Carnegie Institution

OF

Washington

YEAR BOOK

No. 11

1912

CARNEGIE INSTITUTION

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time

to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt bylaws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause

existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Eleventh Meeting of the Board of Trustees

ABSTRACT OF MINUTES OF ELEVENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 13, 1912, and was called to order at 10 o'clock a. m. by the chairman, Mr. Billings.

Upon roll-call by the secretary, the following Trustees responded: John S. Billings, Robert S. Brookings, John L. Cadwalader, Cleveland H. Dodge, Simon Flexner, Henry L. Higginson, Charles L. Hutchinson, Seth Low, S. Weir Mitchell, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, Henry P. Walcott, William H. Welch, Andrew D. White, George W. Wickersham, Robert S. Woodward.

The Founder of the Institution was also present during a part of the meeting.

The minutes of the tenth meeting were approved as printed and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the auditor, directors of departments, and grantees of the Institution were presented and considered.

The following appropriations for the year 1913 were authorized:

Administration	$50,000
Publication	60,000
Division of Publication	10,000
Departments of Research	806,973
Minor Grants	104,300
Index Medicus	12,500
Insurance Fund	25,000
Reserve Fund	250,000
	1,318,773

Amendments to certain By-Laws were adopted, providing for the appointment of an Auditing Committee and of a Fiscal Agent of the Institution, and differentiating more clearly the functions of the Executive Committee from those of the Finance Committee.

The resignation of Mr. Lyman J. Gage was presented and accepted with regret.

Mr. William H. Taft was unanimously re-elected as a member of the Board.

Balloting for officers of the Board for the ensuing three years resulted in the re-election of Mr. Billings as chairman, Mr. Root as vice-chairman, and Mr. Dodge as secretary.

Messrs. Mitchell, Parsons, and Welch were elected as members of the Executive Committee to succeed themselves for a term of three years; Messrs. Low (chairman), Pritchett, and Higginson were re-elected as a Finance Committee for a term of three years; and Messrs. Hutchinson (chairman), Brookings, and Wickersham were elected as an Auditing Committee for the same period.

The Board adjourned at 1:20 p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1912

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV of the By-laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1912, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the eleventh annual report of the Institution and is presented under the following principal heads:

1. Work of administration.
2. Résumé of investigations of the year.
3. Publications.
4. Recommendations of budget for 1913.

ADMINISTRATION.

Death Losses of the Year.

That the progress of individuals is merged with and preserved in the progress of the race is forcibly called to mind by the loss through death during the past year of two associates eminent for their contributions to mathematico-physical science, namely: Prof. Jules-Henri Poincaré and Prof. Lewis Boss, Director of our Department of Meridian Astrometry. Although death has thus far fallen lightly on the scientific staff of the Institution as a whole, it has drawn heavily from the ranks of those devoted to research in astronomy; for the two associates just named and Prof. Simon Newcomb, whose death was recorded three years ago, were all preeminent for their fundamental researches in astronomical science.

Professor Poincaré, whose death occurred July 17, 1912, at the early age of 58 years, was one of the most profound and fertile investigators in the history of science. Like his illustrious predecessors, Lagrange and Laplace, the range of his researches included the entire domain of pure and applied mathematics; and contemporary progress in this domain is due largely to his penetrating generalizations and to his concrete additions of new methods and of new results. His association with the Institution arose in connection with the publication of the Collected Mathematical Works of Dr. George W. Hill (publication No. 9), in which he took a lively interest and for which he contributed an introductory chapter of biography, analysis, and appreciation. His breadth of interest, his originality, and his surpassing clearness in exposition, strikingly typical of his nationality, gave to his works an inspiration for progress which is, and must long remain, peculiarly international.

Prof. Lewis Boss was born at Providence, Rhode Island, October 26, 1846, and died at Albany, New York, October 5, 1912. His preliminary education was obtained in public and private schools of Rhode Island and New Hampshire, and he was graduated from Dartmouth College in 1870. His attention was early directed to the science of astronomy, and soon after leaving college he obtained a position in the United States Land Office at Washington, where he soon came into association with the astronomers of the United States Naval Observatory and the Nautical Almanac Office. On the organization in 1872 of the Northern Boundary Commission for the fixation of that part of the forty-ninth parallel which defines the boundary between the United States and British America, he accepted the position of civilian astronomer under the officers of the Corps of Engineers, United States Army, delegated to represent the United States on this Commission. His duty in this connection probably led him directly into his life work; for the necessity of determining latitudes with precision must have quickly revealed to his mind the nearly total lack at that time of catalogues giving accurate positions of stars suitable for observation in the determination of geographical positions with field instruments. At any rate, he made haste to prepare a catalogue for the special needs of the Boundary Commission, and the greater part of his time and energy was thereafter devoted to this fundamental branch of astronomical research. The catalogue just mentioned was completed early in 1877 and appeared as an appendix to the report of the Commission published by the Department of State. This catalogue gave positions (in declination) for only 500 stars, but it set a new standard of precision, a standard surpassed only recently by Boss himself. While engaged in this work he was appointed director of the Dudley Observatory, Albany, New York, and professor of astronomy in Union University, positions which he held from 1876 to the time of his death.

During this interval of thirty-six years he pursued with rare continuity and unequaled productivity the work of meridian astrometry, for which the Dudley Observatory is specially equipped. He found time, however, for no small amount of attention to allied fields of work, serving as a member of the government eclipse expedition sent to Colorado to observe the solar eclipse of 1878; taking charge of a party sent to Chili by the United States Transit of Venus Commission to observe the transit of the planet Venus across the sun's disk in December 1882; serving the State of New York as superintendent of weights and measures for many years; and more recently acting as editor of the Astronomical Journal. In the meantime he joined in a cooperative effort (originating with the German Astronomical Society) to map accurately all of the brighter stars by dividing the celestial sphere into zones and assigning these respectively to the various observatories adequately equipped for this work. He was one of the earliest to complete a zone and his catalogue of positions of 8241 stars was published at Leipzig in 1890. In the meantime also the magnitude and the importance of increased precision in the determination of stellar positions grew with every

addition to the zonal catalogues and with every other advance in stellar as distinguished from planetary astronomy. It has long been known that the so-called "fixed stars" are not fixed, but it is only recently that something like order has begun to be discovered in the chaos of residual motions hitherto attributed to the stars. Happily for the earlier progress of astronomy, by reason of the great distances asunder of these bodies, their apparent motions are in general small—so small, in fact, that they have been frequently confounded with the small but inevitable errors of observation. Moreover, these "proper motions" as measured by the astronomer are entangled not only with the motions of his observatory in its journey on the earth around the sun, but also with the motion of the entire solar system in space.

It was in the study of these problems of stellar and solar motion that Boss was engaged, independently and almost single-handed, when the Institution came to his aid, first by minor grants made during the years 1904-1906 and then by the establishment of the Department of Meridian Astrometry at the beginning of the year 1906. He had set for himself the stupendous task of producing a catalogue of the highest precision of all stars in both hemispheres, from the brightest to the seventh magnitude inclusive, together with fainter stars of suspected or known proper-motion—a total of about 26,000 stars. It was for this work that he established, under the auspices of the Institution, a temporary observatory at San Luis, Argentina, in 1909. As a contribution to this work also there was published by the Institution, early in 1910, a "Preliminary General Catalogue of 6188 Stars for the Epoch 1900, including those visible to the naked eye and other well-determined Stars." This catalogue immediately took first place among such publications, and the demand for it has been so great that the edition is already nearly exhausted. The positional measurements at the observatory in Argentina were completed early in 1911 and the staff of Professor Boss's department has since been, and is still, engaged on the computations essential to the completion of the comprehensive catalogue just referred to. Fortunately this work is in a favorably forward state, and the plans for its execution are so well laid that it may be completed in due time in accordance with the exacting ideals of its author.

It is a happy circumstance that before his death Professor Boss visualized in large degree the rich harvest of results that must come to sidereal astronomy with the completion of his grand catalogue. From some preliminary papers which he published on the motion of the sun, on the common motion of the stars in the Taurus group, and especially on the systematic motions of the stars and their relations to stellar types, it is evident that he saw plainly how the older branch of positional astronomy, fundamental for geography, geodesy, navigation, and the reckoning of the lapse of time, may come to supplement and to extend the newer branch called astrophysics, which seeks to learn more of the origins, the interrelations, and the destinies of the heavenly bodies. Thus, while he did not live to see the extraordinary task he set for himself completed, he realized a kind of good fortune which

comes probably in larger measure to astronomers than to other investigators; for in his studies of the stars he associated his name for centuries to come with the more enduring phenomena of the universe and passed on to his successors extensive contributions to that sort of knowledge which is verifiable and hence continuously useful to mankind.

Present Status of the Institution.

Although the Institution is quite young and must be considered as still, to some extent, in its formative stages, this first year of the second decade of its history marks an epoch worthy of something more than passing notice. During this year, to a degree hitherto impracticable, there has been opportunity for an objective view of the meaning of the extensive and varied experience, acquired by the Institution, of the principles which have guided its development, and of the limitations, difficulties, and dangers which may beset its future progress. During this year also, to a greater degree than hitherto, have appeared evidences from widely divergent sources of an increasing public tendency to take an objective view of the plan, scope, organization, and development of the Institution and to measure its efficiency by the results of its investigations already published or under way. From these objective views it appears that, in spite of a great diversity of opinion as to what research is and how it should be carried on (a diversity which seems destined to continue indefinitely), there is now a consensus of opinion that the Institution has established its position and demonstrated the practicability of the conduct of effective research in establishments wholly devoted thereto, separate and apart from other establishments whose functions are primarily and commendably agricultural, charitable, commercial, educational, governmental, political, religious, or social. Thus, in general, it may be said that, as regards internal and external relations and interrelations, the Institution in its chosen field of activity has now reached a status approximating to stability of adjustment, wherein definiteness of aim, continuity of effort, and concentration of energy and resources may be more productively applied than heretofore.

But while the work proper of the Institution, namely, work of research, is in a satisfactory condition, as much may not be said of the adventitious work incident especially to the administrative office. For although this latter work is sometimes instructive and occasionally useful, it is generally fruitless and often excessively wasteful of time and energy which might otherwise be turned to better account. This work involves a vast correspondence concerning an endless variety of subjects and particularly concerning an endless variety of objects for which funds might be spent. In its higher phases it is the work of an intelligence office and may be accepted as a not unworthy though unintended function of the Institution; in its lower phases it is in need of curtailment in the interests alike of all concerned.

The time for a detailed, or even summary, account of this highly complex and to some extent psychologically important experience has not yet arrived.

Such an account must be left to historians interested in the evolution of institutions or to analysts, like De Morgan, in search of a mine of materials for a new "Budget of Paradoxes." It is plainly the part of wisdom, however, not to wait for verdicts of the historian and the analyst, but to make use of such inductions as may be safely drawn, not only from the experience just referred to, but also from that gained in the work proper to the Institution. Most of the theories, ideas, and sentiments involved are subject to the tests of statistical treatment which determine with sufficient accuracy the more fruitful methods of procedure. Of the many inductions which may be thus drawn out of the experience of the Institution a few may be here set down as indicative of existing conditions and tendencies.

It is in evidence—

1. That there are the amplest room and the amplest opportunity for research establishments without danger of encroachment on establishments founded for other purposes; that it is not difficult for the Institution to find appropriate ways in which to apply its income; that there are, in fact, in plain sight ten times as many worthy, practicable subjects of research and ten times as many worthy investigators as the income of the Institution can advantageously subsidize.

2. That there are many investigations of such magnitude and difficulty that they can not be carried on economically and effectively except by men untrammeled by other occupations. The common notion that research demands only a portion of one's leisure from more absorbing duties tends to turn the course of evolution backwards and to land us in the amateurism and the dilettantism wherein science finds its beginnings.

3. That it is inimical alike to the interests of society and to those of the Institution to look upon it as a mere disbursing agency designed to meet emergencies or to supply deficiencies of other institutions and of individuals. The widely spread impressions that the income of the Institution is sufficient to meet the aggregate of such emergencies and deficiencies, and that the Institution can undertake to play the rôle of a special providence and thus anticipate the collective needs of deserving individuals and organizations, have no foundations in fact.

4. That while there may be wisdom in a multitude of counsels, it becomes increasingly difficult of access as the multitude enlarges and is generally obscured, if not hidden, by a conflict of opinions. The current popular impression that discoveries and advances may be favorably promoted by the patient examination of a vast aggregate of miscellaneous suggestions is a fallacy abundantly demonstrated by the probably unequaled data available to the Institution.

5. That it is neither practicable nor advantageous for the Institution to undertake to perfect inventions, to secure letters patent for them, to defend inventors in suits at law, or to exploit successful inventions. The objects of the inventor are primarily egoistic and hence secretive; the objects of the Institution are primarily altruistic and hence non-secretive; their divergence

is so great as to render them mutually exclusive under existing conditions. The distinction between invention and investigation is rarely understood and is not always easily drawn. They are indeed closely allied; for the inventor is often compelled to make investigations and the investigator is often compelled to devise inventions. It should be said also that the egoism of the inventor which leads him to secretiveness and to seek state privileges through patent rights has its correlative in the desire of the investigator to secure priority of discovery and publication. The distinction is one of reversed attitudes and objects. The inventor is primarily interested in direct personal benefits which may come from the application of facts and principles in the perfection of useful devices, machines, and processes. The investigator is primarily interested in the discovery of facts and principles which may be given freely to the world without expectation of immediate application or hope of direct personal benefit. It is claimed, however, that the party of the second part to be considered in all such matters, namely, society, is in general disproportionately the gainer over both the inventor and the investigator. The extensive evidence on this subject acquired by the Institution shows clearly that the indirect advantages to the investigator arising from his altruism are generally much greater than the direct advantages to the inventor arising from his egoism. This evidence is, indeed, so convincing as to suggest the desirability, at some future date, of the organization of a department devoted to inventions, which, instead of being protected by patent rights, should be protected, if at all, against them. It is plain, in fact, that if society could make use of knowledge now available the labors of the expert inventor could become far more fruitful, and far more satisfactory to him, than they are at present.

Financial Statement for Fiscal Year 1911-1912.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted and unexpended at the end of the year are shown in detail in the following statement:

Object of appropriation.	Balances unallotted or unexpended Oct. 31, 1911.	Appropriation, Dec. 15, 1911.	Revertments Oct. 31, 1911, to Oct. 31, 1912.	Total.	Aggregates of allotments and amounts expended and transferred.	Balances unallotted or unexpended Oct. 31, 1912.
Large grants	....	$641,100	$8,122.06	$649,222.06	$649,222.06	....
Minor grants	$5,000.00	172,400	1,000.00	178,400.00	172,186.51	$6,213.49
Publications	15,324.33	60,000	4,465.78	79,790.11	62,908.93	16,881.18
Administration	*20,561.22	50,000	3,137.60	73,698.82	53,791.13	*19,907.69
Reserve fund	....	250,000	....	250,000.00	250,000.00	....
Insurance fund	....	23,000	....	23,000.00	23,000.00	....
Total	40,885.55	1,196,500	17,725.44	1,254,110.99	1,211,108.63	43,002.36

* Unexpended amount.

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research	$37,905.00
Department of Economics and Sociology	12,500.00
Department of Experimental Evolution	37,477.00
Geophysical Laboratory	75,000.00
Department of Historical Research	26,600.00
Department of Marine Biology	18,000.00
Department of Meridian Astrometry	26,316.00
Nutrition Laboratory	48,539.06
Division of Publication	10,000.00
Solar Observatory	254,075.00
Department of Terrestrial Magnetism	97,810.00
	644,222.06
Transferred from Nutrition Laboratory to unappropriated fund	5,000.00
	649,222.06

The fields of investigation to which minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the following list:

Details of minor grants.

Field of investigation.	Names of grantees.	Amount of grants.
Astronomy	Gale, Henry G	$1,000.00
	Kapteyn, J. C.	2,000.00
	Störmer, Carl	1,800.00
Archeology	Bandelier, Adolf F	2,000.00
	Frothington, A. L.	750.00
	Van Deman, Esther B.	1,200.00
Bibliography	Index Medicus	12,500.00
Biology	Riddle, Oscar	4,400.00
Botany	Britton, N. L., and Rose, J. N.	3,400.00
	Rose, J. N.	3,600.00
	Fitting, Hans	1,800.00
Chemistry	Acree, S. F.	2,000.00
	Baxter, G. P.	1,000.00
	Osborne, T. B., and Mendel, L. B.	15,000.00
	Jones, H. C.	2,200.00
	Morse, H. N.	4,000.00
	Noyes, A. A.	3,000.00
	Richards, T. W.	3,000.00
	Sherman, H. C.	1,200.00
Climatology	Huntington, Ellsworth	4,000.00
Experimental Evolution	Department of Experimental Evolution	851.75
Geology	Chamberlin, T. C.	4,000.00
	Moulton, F. R.	2,000.00
History	Department of Historical Research	3,000.00
	Osgood, H. L.	500.00
Literature	Bergen, Henry	1,800.00
	Sommer, H. Oskar	2,000.00
Marine Biology	Watson, John B.	500.00
Mathematics	Dickson, L. E.	500.00
	Morley, Frank	1,200.00
Metallurgy	Howe, Henry M.	500.00
Meteorology	Bjerknes, V.	1,800.00
Paleontology	Case, E. C.	2,000.00
	Hay, O. P.	3,000.00
	Wieland, G. R	3,000.00

Details of minor grants—Continued.

Field of investigation.	Names of grantees.	Amount of grants.
Paleography	Loew, Elias A	$1,500.00
Physics	Barus, Carl	500.00
	Hayford, J. F.	2,000.00
	Nichols, E. L.	3,000.00
Physiology	Cooke, Elizabeth	500.00
	Reichert, E. T.	1,500.00
Terrestrial Magnetism	Department of Terrestrial Magnetism	3,600.00
Zoology	Castle, W. E.	2,500.00
	Naples Zoological Station	1,000.00
Administration Building (additions.)		6,462.70
		199,064.45
Transferred:		
Large grants		3,122.06
Unappropriated fund		50,000.00
		172,186.51

The following grants for publication were authorized during the year:

Andrews, C. M.	$1,400.00
Barus, C.	600.00
Benedict, F. G., and E. P. Joslin	1,100.00
Benedict, F. G.	1,136.98
Benedict, F. G., and W. G. Cady	326.01
Burnham, S. W.	3,200.00
Callaway, Morgan, Jr.	3,200.00
Case, E. C.	163.70
Churchill, William	2,500.00
Coblentz, W. W.	300.00
Index to Public State Documents	5,000.00
Jones, Harry C.	900.00
King, Arthur S.	372.52
Lancaster, H. C.	1,000.00
Lehmer, D. N.	$497.50
Loeb, Leo	1,500.00
Mayer, A. G.	262.22
Parker, David W.	1,350.00
Paullin, C. O., and F. L. Paxson	3,000.00
Reichert, E. T.	9,000.00
Researches Dept. of Terrestrial Magnetism	3,000.00
Walcott, C. D.	3,100.00
Total	42,908.93
Transferred to unappropriated fund	20,000.00
	62,908.93

The sources and amounts of the revertments from November 1, 1911, to October 31, 1912, inclusive, are shown in the following list:

Large grants:		
Transferred from minor grants	$3,122.06	
Revertment—Nutrition Laboratory	5,000.00	
		$8,122.06
Minor grants:		
Gale, H. G., Grant No. 760	....	1,000.00
Publication:		
Benedict and Slack, Grant No. 728	183.73	
Case, E. C., Grant No. 669	420.10	
Day and Sosman, Grant No. 717	242.84	
Jones and Strong, Grant No. 716	136.14	
Russell, H. N., Grant No. 668	563.49	
Smith, E. F., Grant No. 665	648.42	
Bjerknes, V., Grant No. 719	366.32	
Case, E. C., Grant No. 672	632.94	
Osborne and Mendel, Grant No. 727	103.04	
Wright, F. E., Grant No. 729	87.97	
Learned, M. D., Grant No. 720	165.68	
Coblentz, W. W., Grant No. 737	25.48	
Nichols and Merritt, Grant No. 726	862.38	
Barus, Carl, Grant No. 804	27.25	
		4,465.78
		13,587.84

Summary of Receipts and Expenditures of the Institution to date.

The aggregate receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refund on grants, and miscellaneous items to date is $7,169,698.80, as shown by the following table:

Year ending Oct. 31—	Interest.		Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
	Endowment.	Bonds and bank deposits.				
1902.......	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903.......	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904.......	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905.......	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.......	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.......	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.......	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909.	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910.......	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.77
1911.......	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.92
1912.......	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.43
	6,575,000.00	203,346.21	70,055.18	15,895.98	*305,401.43	7,169,698.80

* Of this amount, $295,500 were received from the sale of bonds in 1908, 1909, 1910, and 1912.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads, namely: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The actual expenditures under these heads for each year since the foundation of the Institution are shown in the following table:

Year ending Oct. 31—	Investments in bonds and on account of Administration Building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902.....	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903.....	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904.....	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.....	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910.....	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911.....	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912.....	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,937.63
Total..	1,144,640.34	3,566,961.24	1,064,494.81	362,858.93	460,769.52	6,599,724.84

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Administration: Building, site, and equipment		$319,810.70
Publications:		
Stock on hand (Oct. 31, 1912)	$199,328.05	
Outstanding accounts (Oct. 31, 1912)	996.74	
		200,324.79
Department of Botanical Research (Sept. 30, 1912):		
Buildings, office, and operating	37,163.14	
Laboratory equipment	8,090.43	
		45,253.57
Department of Experimental Evolution (Sept. 30, 1912):		
Buildings, office, and library	44,421.60	
Laboratory apparatus	4,673.92	
Operating appliances and grounds	16,200.68	
		65,296.20
Geophysical Laboratory (Sept. 30, 1912):		
Building, library, operating appliances	115,485.79	
Laboratory apparatus	62,286.64	
Shop equipment	13,223.85	
		190,996.28
Department of Historical Research (April 30, 1912):		
Equipment of office and library		3,600.14
Department of Marine Biology (Sept. 30, 1912):		
Vessels	31,674.95	
Buildings, docks, furniture, and library	10,553.26	
Apparatus and instruments	3,671.79	
		45,900.00
Department of Meridian Astrometry (July 31, 1912):		
Buildings and operating appliances	13,521.70	
Apparatus and instruments	2,394.34	
		15,916.04
Nutrition Laboratory (Sept. 30, 1912):		
Building, office and shop	112,765.82	
Laboratory apparatus	12,317.98	
		125,083.80
Solar Observatory (Aug. 31, 1912):		
Buildings, grounds, road, and telephone line	168,500.42	
Shop equipment	19,574.01	
Instruments	334,130.48	
Furniture and operating appliances	62,327.18	
Hooker 100-inch reflector	63,458.56	
		647,990.65
Department of Terrestrial Magnetism (Sept. 30, 1912):		
Office	5,016.36	
Instruments	35,019.82	
Vessel and ocean equipment	117,212.14	
Land equipment	1,246.20	
		158,494.52
		1,818,666.69

RÉSUMÉ OF INVESTIGATIONS OF THE YEAR.

Departments of Research.

It is now nine years since the earliest of the departments of research established by the Institution were authorized and six years since the latest of them was authorized. This lapse of time has now fully demonstrated that these departments are all engaged in enterprises which, by reason of their magnitudes, were unlikely to be carried out under other auspices. They have grown very rapidly and have become highly productive. All of them tend continually, and in many respects properly, to expand as their several fields of investigation are developed. They thus tend constantly to press closely upon the available income of the Institution and hence to become a source of concern by reason of their highly commendable progress. But the remedy for this paradox does not lie alone in increased expenditures; to an equal extent, at least, it lies in increased efficiency under slowly increasing, or even stationary or decreasing, expenditures. It is a special duty of the man of science to show how more and better work can be done at less cost than has been practicable to his predecessors.

Although these departments of investigation, like the Institution as a whole, have fallen short of popular expectations in the rapidity of their growth, it now appears plain, in the light of their actual experience, that this growth has been somewhat too rapid for safety. Along with this rapid growth and with the signal success of these departments in their several fields of research, there are now coming also numerous requests for cooperation with other organizations and with individuals. But while these requests are in general gratifying and often praiseworthy, they present some obvious hazards. There is need, therefore, of constant caution against the dangers of undue expansion and affiliation which lead to dissipation of effort and resources. It should be kept in mind that concentration on definitely limited programs, continuity of effort, and energetic assiduity are the factors most essential to progress in the domain of research.

The plan referred to a year ago, of inviting one or two eminent specialists to become associated with each of the departments for limited periods of time, has thus far worked quite advantageously and promises to become increasingly fruitful. Eight such specialists have been connected with the departments during the past year by direct appointment of the Executive Committee, with varying compensations, as shown in the financial section of this report. Some other Research Associates have served without compensation and several collaborators have also partaken in departmental investigations or availed themselves of departmental facilities without direct expense to the Institution.

As usual, in the President's report, reference must be made to the departmental reports, to be published in full in the current Year Book, for comprehensive accounts of departmental investigations, publications, and plans

for future activities, as well as for accounts of the work of departmental associates and collaborators. Only the briefest summaries, indicating some of the salient features of these accounts, are attempted in the following paragraphs.

Department of Botanical Research.

The geographical range of the work of this department, which centers in the Desert Laboratory at Tucson, Arizona, has been extended during the past year to include certain portions of the deserts of northern Africa. Thus Dr. Cannon spent the late autumn and early winter of 1911–1912 in the deserts of Algeria, while Director MacDougal and his engineer, Mr. Sykes, spent a good share of the winter of 1911–1912 in the Libyan deserts. These expeditions enabled the department to acquire extensive information for comparative studies of desert areas, and Dr. Cannon's report on the results of the earlier expedition has been already received for publication.

Studies have been continued also at the Desert Laboratory, at the Carmel Laboratory on the California coast, at Salton Sea, and at various substations where observations are made on the phenomena presented by plants under strikingly varying conditions. The desiccation of the Salton Sea now under observation presents many instructive conditions which are being carefully studied in their climatic, biological, and physical aspects. It will be practicable, therefore, in the course of a few years, to furnish something like a detailed history of this remarkable basin, which has now been carefully studied at intervals since its discovery in 1854 by the late Professor N. P. Blake.

One of the most important investigations undertaken during the past year is that of a comprehensive study of the large and highly diversified family of cactus plants. Through the cooperation of Prof. N. L. Britton, Director of the New York Botanical Garden, and Dr. J. N. Rose, of the staff of the Smithsonian Institution, who have been appointed Research Associates, it will be practicable, by aid of the facilities of the department, to produce a monographic study of these typical desert plants.

Several volunteer associates and collaborators of the department have participated in departmental researches and contributed to the progress attained therein. Upwards of twenty individuals have taken part in one or more phases of this work.

Department of Experimental Evolution.

The advances made by this department during the past year have been chiefly along the lines of studies in cytology, in the chemistry of pigmentation, in the factors of mutation, and in the problems of human heredity. These studies have been carried on by aid of experiments with plants and animals and by aid of rapidly accumulating statistical data concerning human traits and their transmission through successive generations. The Director has been able to give much of his time to studies in human heredity by reason of his connection with the Eugenics Record Office, whose work has been liberally supported

by Mrs. E. H. Harriman and by Mr. John D. Rockefeller. The experiments of the department proper with plants and animals are thus supplemented very advantageously by the extensive information already acquired by the Eugenics Record Office in respect to human heredity.

Very interesting chemical studies have been carried on by Dr. Gortner, a member of the staff, in respect to the chemical nature of pigments which determine color characteristics, especially of the plumage in birds, of the wool in sheep, and of the skin in men.

Dr. Shull has continued his fertile studies into the heredity of plants, including further investigations into the connection between heredity and environment in the case of corn. These further studies confirm his earlier conclusions and show also that the hereditary traits of different strains are maintained irrespective of environmental influences.

The Director calls attention to the need of his department for additional buildings and equipments. A recommendation with respect to this need will be found in a subsequent part of this report.

Department of Economics and Sociology.

According to the report of Prof. Henry W. Farnam, Chairman, the work of this department has now reached such a stage of advancement that the time of its completion depends mainly on the amount of leisure the collaborators may obtain in the near future for consecutive attention to their several contributions to the "Economic History of the United States." By aid of the special appropriation for payment of salaries (made by the Board of Trustees a year ago), it is now practicable for some of the collaborators to devote part of their time and attention consecutively to this work, and two or three of them will doubtless be able to give at least half-time under this plan during the ensuing year. The present status of the investigations of the several divisions of the department is set forth in detail by the Chairman in his report.

The attention of the Trustees is especially invited to a paragraph in Professor Farnam's report calling attention to the desirability of a more permanent organization of this department before its present program of research is completed. He recommends an organization similar to that of other departments of the Institution, which would involve the appointment of a salaried director and a permanent staff. The experience of the Institution leaves no doubt as to the wisdom of this recommendation on the score of continuity and efficiency for this as well as for other departments of the Institution. Further reference to this subject will be made in the budget section of this report.

Geophysical Laboratory.

The list of twenty-four publications which have emanated from the Geophysical Laboratory during the past year, and which are briefly reviewed by the Director in his annual report, furnishes the best index of the activity of this establishment. Two specially noteworthy publications of the Laboratory have been issued

during the year by the Institution, namely, No. 157, "High Temperature Gas Thermometry," and No. 158, "The Methods of Petrographic-Microscopic Research." The purpose of the first of these was to give an account of the apparatus and methods for accurate measurement of the critical temperatures incident to mineral combinations; and the object of the second is to place, so far as practicable, microscopic study of minerals upon a quantitative basis. Attention has hitherto been called to this characteristic feature of the investigations of the Geophysical Laboratory, which is a characteristic feature of all of the advancing sciences. The work already accomplished demonstrates the practicability of achieving this object for the science of mineralogy. This advance requires that special attention be given to accurate measurements of high temperatures and high pressures, as well as to their simultaneous effects upon mineral constituents. Much study, therefore, continues to be given by the Laboratory staff to the development of effective apparatus and technique for the measurements essential in this work.

Special attention is called in the Director's report to extended studies on quartz and other forms of silica, which is the most widely diffused ingredient in rock masses; to further experiments on the conditions of association of the three oxides, lime, alumina, and silica, which in addition to being the commonest components of igneous rocks are also incidentally the three principal ingredients of the so-called Portland cement; to mineral sulphides, which are often of great economic importance; and to mineral and rock densities.

Perhaps the most interesting of the more recent investigations of the Laboratory are those of the physics and chemistry of active volcanoes undertaken tentatively a year ago and pursued with very gratifying success during the past summer. It has proved practicable for members of the staff to descend into the crater of Kilauea and to collect considerable quantities of gas as it emerged from the liquid lavas of the crater. Specimens of gases were collected in glass tubes without contamination from the air, and these have been brought to the Laboratory at Washington for detailed study. There seems little reason to doubt that the phenomena of vulcanism will be ultimately revealed by the methods, apparatus, and technique developed by the staff of the Laboratory.

Department of Historical Research.

Naturally a department devoted to historical research is chiefly concerned with the preparation of publications, and these latter for the department in question may be classified under the head of reports, aids, and guides concerning materials relating to American history and under the head of textual publications of documents. Under the first head attention may be called to Prof. Marion D. Learned's "Guide to the Manuscript Material Relating to American History in German State Archives," No. 150 of the publications of the Institution, which has appeared during the year. Two other volumes, namely, publication No. 90A, "Guide to the Materials for American History, to 1783, in the

Public Record Office of Great Britain," and publication No. 163, "Guide to the Materials for the History of the United States in the Principal Archives of Mexico," of the Institution are now in press. No. 90A has been somewhat delayed by reason of a reclassification to which large sections of the British Public Record Office were subjected after this work had been started by Professor Andrews. Another work in press by the department is Mr. David W. Parker's "Guide to the Materials for United States History in Canadian Archives," publication No. 172 of the Institution.

Further progress is reported in respect to the work in charge of Mr. W. G. Leland, of the departmental staff, on materials for American history in the archives of Paris. Search has been made also in several other European cities for sources of American history. The Director of the department spent the past summer in Europe and took occasion while there to devote special attention to the materials derivable from the five French-speaking cantons of Switzerland. Assistance has been rendered to the department during the year by several collaborators who have been called by the Director to his aid in the preparation of the proposed atlas of historical geography of the United States, to which reference has been made in preceding reports.

Dr. Burnett, of the departmental staff, has been engaged chiefly upon the series of "Letters of Delegates to the Continental Congress," while Miss Davenport, also of the permanent staff, has been occupied nearly continuously in the collection of "European Treaties having a bearing on United States History." These documents promise to furnish much material hitherto inaccessible to students of American history.

Department of Marine Biology.

The independent transportation facilities furnished by the staunch new vessel, *Anton Dohrn,* and the repairs and improvements to the Laboratory completed a year ago, have proved highly advantageous to the Department of Marine Biology. By means of the *Anton Dohrn* the entire Gulf and West Indian region becomes open to investigation by the department. The Director records with appreciation a gift to his fleet by Hon. John B. Henderson, of Washington, D. C., of a 23-foot, 6 horse-power launch, which has already proved a very useful adjunct in the diversified work of the department, since many different investigations are carried on simultaneously by different individuals at the laboratory headquarters.

During February and March of the current year the Director established a temporary laboratory at Montego Bay, Jamaica, a region which sustains important biological relations to the vicinity of the Tortugas group of islands. In addition to the Director, nine other investigators pursued researches at this laboratory. In May the Director and three collaborators visited the Bahamas, making a successful cruise of 570 miles with the *Anton Dohrn.* This expedition was of special aid to Messrs. Drew and Vaughan in their studies concerning oolite deposits and corals.

The Director of the department has issued, as No. 162 of the publications of the Institution, an additional volume of his series on the jelly-fishes of the world, the title of this volume being "Ctenophores of the Atlantic Coast of North America." Sixteen of his collaborators have presented papers for publication, which will furnish two more volumes of the "Researches from the Tortugas Laboratory."

Department of Meridian Astrometry.

After the meridian instrument was brought back from the temporary observatory at San Luis, Argentina, to the Dudley Observatory at Albany, it was thoroughly reexamined to make certain that it had undergone no change on account of the relatively rough handling it necessarily received during this journey from Argentina to America. The reexamination was completed about the beginning of the present fiscal year and proved conclusively that the instrument had suffered no damage in any of its parts. Along with this good fortune to the department and to the Dudley Observatory, this instrument thus becomes noteworthy in the annals of astronomy, for no meridian circle has been so thoroughly proved to retain its stability under such a variety of varying conditions. After the preliminary tests referred to, observations with the instrument were begun on November 13, 1911, and have continued throughout the year, in accordance with the program explained hitherto in the departmental reports.

In the meantime special attention has been given to the reduction of the meridian observations made at San Luis, Argentina. The determination of the two coordinates of stars from this work, namely, right ascension and declination, have proceeded simultaneously. The assignment of stellar magnitudes, however, must await the photometric determinations which have been made at San Luis since the meridian measurements were completed. Late advices from Mr. Zimmer, who has charge of this photometric work, announce that it will be completed by the end of the present calendar year, and he and his assistant are expected to return early next year.

The department reports with great regret the death, on November 19, 1911, by accidental drowning, of Mr. William Hunt, who served initially as Mr. Zimmer's assistant. Mr. Hunt was a young man of much promise, and his untimely loss was a source of shock to his colleagues and a cause of temporary delay to the photometric work.

Much attention has been given by the Director of the department and by Mr. Benjamin Boss to studies of stellar motions for which the extensive data accumulated by the department are furnishing evidence. These studies and those made by the Solar Observatory of the Institution, along with corresponding investigations in many other observatories, indicate that the progress of astronomy in the future is to be no less brilliant than it has been in the past.

The great quantity of priceless observational and derived data accumulated by the department rendered it imperative that special provision should be made for their safe storage. Accordingly the Executive Committee authorized the department to expend, from its last annual allotment, the sum of $2,000 for the construction of a fire-proof vault within the walls of the Dudley Observatory. This vault is now ready for occupancy and the records will be placed therein as soon as practicable.

Nutrition Laboratory.

Although investigations began immediately on the establishment of the Nutrition Laboratory five years ago, the novelty and importance of its field have called for continuous additions to its equipment, while added experience has suggested many improvements in the apparatus used. Thus during the past year two balconies have been added to the calorimeter laboratory, a treadmill designed to measure severe muscular work has been provided for a respiration chamber, and numerous modifications have been made in the calorimeters and respiration apparatus of the Laboratory. More detailed studies of the bicycle ergometer, which has hitherto proved so useful in experiments on the metabolism of man during excessive muscular work, have rendered the apparatus available over a wider range of experimentation and with a higher degree of certainty than hitherto. The importance and success of the experiments already undertaken at the Laboratory have created a widespread interest in the medical profession, and this interest has led to many cooperative investigations undertaken during the past year. The novel equipment of the Laboratory has been the subject of much inquiry also, and many investigators from other laboratories have sought to secure copies of the apparatus used and to learn more of the technique developed by the Director and his staff.

One of the most interesting of the many investigations under way during the year is that of the metabolism of a subject who underwent a prolonged fast, extending to thirty-one days without food, and who drank only distilled water during this time. This investigation required the cooperation of a number of chemical, pathological, and psychological experts. A detailed report on this elaborately observed experiment is at present in preparation. Another noteworthy investigation of the year is that on metabolism during severe muscular work, undertaken by Dr. E. P. Cathcart, of the University of Glasgow, who was a Research Associate of the Institution during the winter of 1911–1912. Amongst other important results of the latter research is the measure it affords of the mechanical efficiency of man. An account of this investigation is likewise in preparation for publication.

In addition to the numerous papers which have appeared in current journals from the Laboratory, two volumes, Nos. 166 and 167 of the Institution's series, have been issued during the year. The first of these is devoted

to "The Composition of the Atmosphere with Special Reference to its Oxygen Content," and proves the remarkable fact of the essential constancy of this element in the atmosphere.

Department of Terrestrial Magnetism.

Highly effective progress has been made by this department during the past year in its magnetic survey of the globe. By means of the non-magnetic ship *Carnegie* it is now easier to make a magnetic survey of the ocean areas than of the land areas, for the former are now more readily accessible than the latter. At the end of the preceding fiscal year the *Carnegie* was at Batavia, Java. On November 21, 1911, she set sail for an additional circuit of the Indian Ocean, whence she proceeded to Manila, Philippine Islands, where she arrived February 3, 1912. From Manila she proceeded to Suva, thence to Tahiti, and is now en route to Coronel, Chili. During the fiscal year she traversed about 28,000 miles. Her courses are arranged to intersect as frequently as possible her own previous tracks, those of the *Galilee,* and those of previous expeditions on which magnetic elements were observed. Valuable checks on the determinations of these elements are thus secured, and in case of considerable intervals between the dates of different determinations, data for secular variation of the magnetic elements are also obtained. As related in the report of a year ago, unexpectedly large errors were found in the best magnetic charts of the Indian Ocean and for some parts of the Pacific Ocean. In order that corrections may be speedily applied to such charts the results of the cruises of the *Carnegie* are promptly made known to the principal hydrographic offices of the world. It is expected that the *Carnegie* will complete her present circumnavigation of the world near the end of the next fiscal year.

Observations have been continued simultaneously on land areas, embracing portions of five continents and about twenty different countries. Many noteworthy series of transcontinental stations have now been completed. Of these, one extending across the entire continent of South America, beginning at Para, at the mouth of the Amazon, and extending to Callao on the Pacific coast, by way of the Amazon and Ucayali rivers and Lima, has been finished during the past year.

The first volume of researches of the department, giving the results of land observations from the time of its establishment in 1905 down to the end of the year 1910, is now in press. The final computations of the ocean observations made during the various cruises of the *Galilee* and the *Carnegie* are also well advanced for a second volume. Many improvements in instrumental appliances have been made during the year in response to needs and suggestions arising from the extensive experience of the department on land and sea. One of the most important of the new appliances devised is that called an "earth inductor," which permits the measurement of the dip of the magnetic needle with increased precision and decreased labor over

devices previously used. An attempt is now being made to apply this apparatus, which has proved completely successful on land, to the determination of dips on the *Carnegie.*

Solar Observatory.

The past year has been one of minimum sun-spot activity; but effective progress has been made in many other branches of solar and stellar research undertaken by the Observatory. The wide range of this work may be indicated by the fact that the results of the investigations of the year are summarized by the Director under thirty-five different heads. The new tower telescope has been completed and important auxiliary apparatus has been added to the equipment of the 60-inch reflector. A fire-proof office building, which will afford adequate quarters for the staff and safety for the original records and photographic plates of the Observatory, has been constructed and made ready for occupancy during the year.

The 150-foot tower telescope with its spectrograph and spectroheliograph has been tested and found to be quite up to expectations. The 60-inch reflector has proved increasingly effective in the wide variety of work undertaken with it. Between forty and fifty new spectroscopic double stars have been found; and amongst the many stars whose radial velocities have been measured is one which surpasses all others hitherto observed, its velocity being about 150 miles per second.

Two eminent Research Associates, namely, Professor Kapteyn, of Groningen, and Professor Störmer, of Christiania, have taken part in the work of the Observatory during the year. Professor Kapteyn, who has served in this capacity for several years previously, has been of great service to the department, especially in the planning of a program of work with the 60-inch reflector, so that it may yield a maximum return alike for problems of stellar distribution and stellar development. Professor Störmer, who is one of the highest authorities concerning auroras, has sought to determine especially the connection of these phenomena with the sun. Of their connection with the sun and with the earth's magnetism there is little doubt, and the recent demonstration of the atomicity of matter in general and the atomic nature of electricity in particular may be confidently expected to lead to distinct advances in our knowledge of these phenomena in the near future.

The laborious task of shaping and testing the glass disk for the proposed 100-inch telescope has proved a disappointment in showing that this disk, which was accepted provisionally from the makers several years ago, will not answer the requirements. At this writing it appears possible that some expedients may be adopted to overcome the instability of this disk; but the probability that it may be made to work satisfactorily is small. In the meantime the makers of such large disks have not succeeded in making one of sufficient uniformity in density. In view of these difficulties the Director is disposed to try a thinner disk if one can be found possessing the requisite

degree of homogeneity. Thus this project must suffer further delay, although it is practically certain that the difficulties presented may be ultimately overcome.

Investigations of Research Associates and Collaborators.

The relations of Research Associates and collaborators of the Institution are so diversified and complex that they are difficult to specify at any given epoch. Individuals who have received direct aid during the year to their investigations through grants are mentioned in the preceding financial section of this report. Those who have received indirect aid through grants made for the publication of their researches are also mentioned in the section just referred to. Many collaborators and assistants have received compensation directly from Research Associates in charge of investigations, while some Research Associates and many collaborators have received no direct compensation. It appears to be neither desirable nor practicable at present to seek any higher degree of correlation of this work, since it is carried on by many individuals in many different parts of the world. The best evidences of the quantity and quality of the results accomplished are to be found in the publications listed in part in a subsequent section of this report and more at length in the general bibliography of the year published in the current Year Book. The work of the year has extended to an aggregate of more than twenty different fields of research and has occupied the attention of more than a hundred investigators. Many of these have rendered special reports to be published in the Year Book, while reference is made to the work of many others in the reports of the larger departments of research.

PUBLICATIONS.

Publications Authorized and Issued During the Year.

The publication of seventeen volumes* has been authorized by the Executive Committee during the year at an aggregate estimated cost of $36,250. The following list gives the titles and names of the authors of the publications issued during the year. It includes 23 volumes, with an aggregate of 3,981 octavo pages and 2,044 quarto pages. Thirty-two additional volumes are now in press.

List of Publications issued during the year.

Year Book No. 10, 1911. Octavo, XVI + 296 pages, 9 plates.
Index Medicus, Second Series, vol. 9, 1911. Octavo, 1585 pages.
No. 74. Sommer, H. Oskar. Vulgate Version of the Arthurian Romances. Edited from MSS. in the British Museum. Quarto. Vol. V. Le Livre de Lancelot del Lac, Part III, 474 pages.
No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Prepared for and under the direction of the Department of Economics and Sociology of the Carnegie Institution of Washington. Separate volumes for each State. Quarto. Ohio. Two volumes, 1136 pages.
No. 88. Bjerknes, V., Th. Hesselberg, and O. Devik. Dynamic Meteorology and Hydrography. Part II, Kinematics. Quarto, IX + 175 pages, 113 text figures. Atlas of 60 charts.
No. 146. Case, E. C. Revision of the Amphibia and Pisces of the Permian of North America. Quarto, 184 pages, 32 plates, 56 text figures.
No. 149. Barus, Carl. The Production of Elliptic Interferences in Relation to Interferometry. Part II. Octavo, VI + 79-168 pages, text figures 34-64.
No. 150. Learned, Marion D. Guide to the Manuscript Material relating to American History in the German State Archives. Octavo, VII + 352 pages.
No. 152. Nichols, Edward L., and Ernest Merritt. Studies in Luminescence. Octavo, 226 pages, 190 text figures.
No. 153. King, Arthur S. The Influence of a Magnetic Field upon the Spark Spectra of Iron and Titanium. Quarto, 66 pages, 3 text figures.
No. 156. Osborne, Thomas B., and Lafayette B. Mendel. Feeding Experiments with Isolated Food-Substances. Part II. Octavo, pages III + 55-138, text figures XXII-CXXIX.
No. 158. Wright, F. E. The Methods of Petrographic-Microscopic Research: Their Relative Accuracy and Range of Application. Octavo, 204 pages, 11 plates, 118 text figures.
No. 160. Jones, Harry C., and W. W. Strong. The Absorption Spectra of Solutions of Comparatively Rare Salts, including those of Gadolinium, Dysprosium, and Samarium; the Spectrophotography of Certain Chemical Reactions, and the Effect of High Temperature on the Absorption Spectra of Non-aqueous Solutions. Octavo, VIII + 112 pages, 67 plates.
No. 162. Mayer, Alfred G. Ctenophores of the Atlantic Coast of North America. Octavo, 58 pages, 17 plates, 12 text figures.
No. 164. Coblentz, W. W. A Physical Study of the Firefly. Octavo, 47 pages, 1 plate, 14 text figures.
No. 166. Benedict, Francis G. The Composition of the Atmosphere with Special Reference to its Oxygen Content. Octavo, 1 plate, 1 text figure, 115 pages.
No. 167. Benedict, Francis G., and Walter G. Cady. A Bicycle Ergometer with an Electric Brake. Octavo, 44 pages, 16 text figures.
No. 170. Jones, Harry C. The Electrical Conductivity, Dissociation, and Temperature Coefficients of Conductivity (from Zero to Sixty-five Degrees) of Aqueous Solutions of a Number of Salts and Organic Acids. Octavo, IV + 148 pages.

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* The names of the authors of these volumes are given in the financial statement on page 14.

No. 174. Churchill, William. Easter Island: The Rapanui Speech and the Peopling of Southeast Polynesia. Octavo, 340 pages.

Classics of International Law. Zouche, Richard. Juris et Judicii Fecialis, sive, Juris inter Gentes et Quæstionum de Eodem Explicatio. Edited by Thomas Erskine Holland. Vol. II. A Translation of the Text, by J. L. Brierly. Pages XVII + 186.

Pamphlet issued on the occasion of the Tenth Anniversary of the Institution, Dec. 14, 1911. Octavo, 35 pages, 1 plate, 27 figures.

Sales of Publications and Value of Those on Hand. The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing Sales of Publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903	$2,256.91	$29.25	....
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970.56	37.60	1,341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
1912	4,652.14	61.65	6,782.34
Total..	35,628.30	641.46	33,785.42

At the end of the fiscal year just closed there are on hand 82,989 volumes of miscellaneous publications and Year Books, having a sale value of $186,024.05. There are also on hand 28,816 numbers, or the equivalent of about 2,215 volumes, of the Index Medicus, having a sale value of $13,304. The total value of publications on hand is therefore $199,328.05.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent, also, by sales, a total of 100,869 volumes of publications of the Institution.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit at the annual meeting of the Board of Trustees a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1911–1912.

During the fiscal year ending October 31, 1912, the Executive Committee held eleven meetings, including a special joint meeting with the Finance Committee on January 18, 1912. Printed reports of these meetings have been sent to the Trustees of the Institution.

Upon the adjournment of the Board of Trustees on December 15, 1911, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1912, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1911–1912, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits various recommendations and suggestions and an outline of suggested appropriations for the year 1913. The Executive Committee hereby approves the report of the President, and his recommendations, as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 15, 1911, appointed the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1912, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a balance sheet, showing the condition of the assets and liabilities of the Institution on October 31, 1912, together with statements of receipts and disbursements for the fiscal year and of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

There are no vacancies in the Board of Trustees as now limited, but the terms of office of the following members of the Board will expire at the

coming annual meeting: Mr. Billings as Chairman of the Board, Mr. Root as Vice-Chairman, Mr. Dodge as Secretary, Messrs. Mitchell, Parsons, and Welch as members of the Executive Committee, and Messrs. Low, Higginson, and Pritchett as members of the Finance Committee.

WILLIAM H. WELCH, *Chairman.*
JOHN S. BILLINGS.
CLEVELAND H. DODGE.
S. WEIR MITCHELL.
WM. BARCLAY PARSONS.
ELIHU ROOT.
CHARLES D. WALCOTT.
ROBERT S. WOODWARD.

November 22, 1912.

Balance Sheet, October 31, 1912.

ASSETS.

INVESTMENTS:		
Securities (page 36)		$22,531,941.87
PROPERTY ACCOUNT:		
Real estate, equipments, and publications (page 37)		1,818,666.69
CURRENT ASSETS:		
Cash	$569,973.96	
Stamps and petty cash	300	
		570,273.96
		24,920,882.52

LIABILITIES.

ENDOWMENT		$22,000,000
SUNDRY RESERVE FUNDS:		
Reserve fund	$511,583.56	
Insurance fund	54,247.56	
		565,831.12
INVESTED IN PROPERTY		1,818,666.69
CURRENT LIABILITIES:		
Large grants	269,642.71	
Minor grants	53,461.79	
Publication	88,479.63	
Administration	19,907.69	
		431,491.82
UNAPPROPRIATED FUND		104,892.89
		24,920,882.52

Statement of Receipts and Disbursements from November 1, 1911, to October 31, 1912.

RECEIPTS.

INTEREST:			
Endowment—			
Bonds	$1,100,000		
Bank balance	12,737.67	$1,112,737.67	
Reserve Fund—			
Bonds	13,568.75		
Bank balance	649.50	14,218.25	
Insurance Fund—			
Bonds	2,000		
Bank balance	195.82	2,195.82	
Income investment bonds		1,966.67	$1,131,118.41
SALES OF PUBLICATIONS:			
Index Medicus		4,652.14	
Year Book		61.65	
Miscellaneous Books		6,782.34	11,496.13
REFUND ON GRANTS:			
Grant No. 674		904.50	
711		28.91	
739		501.60	
708		222.22	
746		1.65	1,658.88
MISCELLANEOUS:			
Sale of paper		521.44	
Refund, Trustees		32.03	
printing		204.99	
shipping		21.55	
office		5	785.01
SALE OF BONDS:			
Lake Shore and Michigan Southern		47,000	
Central Pacific Railway Co		48,250	95,250
			1,240,308.43
Balance from last report to Trustees, Oct. 31, 1911			476,703.16
			1,717,011.59

DISBURSEMENTS.

INVESTMENT:		
Bonds, reserve fund		$436,276.03
GRANTS:		
Large	$519,673.94	
Minor	103,241.73	622,915.67
PUBLICATION		44,054.80
ADMINISTRATION:		
Trustees	4,476.20	
Executive Committee	2,080.43	
Salaries	24,875	
Publication—shipping expenses	4,206.86	
Sureties, rent, telephone	348.33	
Equipment	590.03	
Stationery	282.52	
Postage, express, telegrams	554.91	
Printing	*2,826.75	
Office supplies and petty expenses	630.21	
Building and grounds—		
Supplies and janitor service	1,944.06	
Fuel, light, water	975.83	43,791.13
		1,147,037.63
CASH ON DEPOSIT:		
United States Trust Co., New York	527,567.19	
United States Trust Co., New York, reserve fund	29,697.94	
National City Bank, New York	6,914.30	
Am. Security and Trust Co., D. C.	5,794.53	569,973.96
		1,717,011.59

* Including Year Book for 1911.

Statement of Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1912.

RECEIPTS.

Interest:		
Endowment bonds	$6,575,000	
Reserve Fund bonds	15,068.75	
Insurance Fund bonds	2,000	
Income and Building Fund bonds	94,005.56	
Deposits in banks	92,271.90	
		$6,778,346.21
Sales of Publications:		
Index Medicus	35,628.30	
Year Book	641.46	
Miscellaneous	33,785.42	
		70,055.18
Refund on Grants	....	15,895.98
Miscellaneous:		
Organization	1,825.52	
Sale of furniture	69	
Gas deposit	5.36	
Postage, express, and travel	56.65	
Printing and paper	2,607.35	
Sale of metal cuts	61.80	
separates	213.77	
Refund, shipping	179.30	
grounds	38.46	
office	47.66	
insurance	4,717	
operating	18	
telephone, light	29.53	
Trustees	32.03	
		9,901.43
Sale of Bonds:		
Northern Pacific-Great Northern	48,000	
Northern Pacific	102,750	
Atchison, Topeka, and Santa Fe	49,500	
Lake Shore and Michigan Southern	47,000	
Central Pacific	48,250	
		295,500
		7,169,698.80

DISBURSEMENTS.

Investment:		
Bonds	$834,724.65	
Administration Building and Site	309,915.69	
		$1,144,640.34
Grants:		
Large	3,566,961.24	
Minor	1,064,494.81	
		4,631,456.05
Publication	....	362,858.93
Administration:		
Trustees	22,363.50	
Executive Committee	17,522.15	
Honorariums to advisers	17,319.81	
Salaries	275,488.03	
Publication—shipping expenses	11,854.88	
Rent, surety, telephone	28,827.94	
Equipment	11,917.01	
Stationery	11,967.99	
Postage, express, and telegrams	19,020.24	
Printing	*25,442.50	
Office expenses	2,138.54	
Building and grounds—		
Supplies and janitor service	6,568.96	
Fuel, light, water	2,612.92	
Organization	1,825.52	
Plans and option	5,166.46	
Seal	555.60	
Miscellaneous	70.23	
		460,662.28
Refund:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		6,599,724.84
Cash in Banks		569,973.96
		7,169,698.80

* Including Year Books.

Schedule of Securities.

Par value.	Securities.	Nominal value.	Total.
	ENDOWMENT		
$10,000,000	U. S. Steel Corporation, Series B, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	$10,000,000	
2,000,000	U. S. Steel Corporation, Series A, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	2,000,000	
2,500,000	U. S. Steel Corporation, Series C, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	2,500,000	
2,500,000	U. S. Steel Corporation, Series D, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	2,500,000	
2,500,000	U. S. Steel Corporation, Series E, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	2,500,000	
2,500,000	U. S. Steel Corporation, Series F, Registered 50-year 5 p. ct. Gold Bonds, due April 1, 1951..	2,500,000	$22,000,000
	INSURANCE FUND	Purchase price.	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage, 100-year 4 per cent Registered Gold Bonds, due 1995..........	50,056.25	50,056.25
	RESERVE FUND		
50,000	American Telephone and Telegraph Company, Collateral Trust 4 per cent Bonds, due 1929	45,500	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4 per cent Registered Gold Bonds, due 1949..........	48,250	
15,000	Great Northern Railway Company, First and Refunding Mortgage 4¼ per cent Bonds, due 1961..........	15,227	
130,000	General Electric, 5 per cent Gold Debenture Bonds..........	132,184.72	
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4 per cent Gold Bonds, due September 1, 1928..........	47,000	
50,000	Long Island Railroad Company, Refunding Mortgage 4 per cent Bonds, due 1949.......	48,285	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½ per cent Bonds, due 1946..........	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy Collateral), Joint 4 per cent Bonds, due 1921..........	49,876.40	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4 per cent Mortgage Bonds, due 1961..........	46,375	481,885.62
22,545,000			22,531,941.87

Schedule of Real Estate, Equipments, and Publications.

ADMINISTRATION:		
Building, site, and equipment	....	$319,810.70
PUBLICATIONS:		
Books on hand (October 31, 1912)	$199,328.05	
Outstanding accounts (October 31, 1912)	996.74	
		200,324.79
DEPARTMENT OF BOTANICAL RESEARCH (SEPT. 30, 1912):		
Buildings, office, and operating	37,163.14	
Laboratory equipment	8,090.43	
		45,253.57
DEPARTMENT OF EXPERIMENTAL EVOLUTION (SEPT. 30, 1912):		
Buildings, office, and library	44,421.60	
Laboratory apparatus	4,673.92	
Operating appliances and grounds	16,200.68	
		65,296.20
GEOPHYSICAL LABORATORY (SEPT. 30, 1912):		
Building, library, operating appliances	115,485.79	
Laboratory apparatus	62,286.64	
Shop equipment	13,223.85	
		190,996.28
DEPARTMENT OF HISTORICAL RESEARCH (APRIL 30, 1912):		
Office equipment	1,221.32	
Library	2,378.82	
		3,600.14
DEPARTMENT OF MARINE BIOLOGY (SEPT. 30, 1912):		
Vessels	31,674.95	
Buildings, docks, furniture, and library	10,553.26	
Apparatus and instruments	3,671.79	
		45,900.00
DEPARTMENT OF MERIDIAN ASTROMETRY (JULY 31, 1912):		
Buildings and operating appliances	13,521.70	
Apparatus and instruments	2,394.34	
		15,916.04
NUTRITION LABORATORY (SEPT. 30, 1912):		
Building, office, and shop	112,765.82	
Laboratory apparatus	12,317.98	
		125,083.80
SOLAR OBSERVATORY (AUG. 31, 1912):		
Buildings, grounds, road, and telephone line	168,500.42	
Shop equipment	19,574.01	
Instruments	334,130.48	
Furniture and operating appliances	62,327.18	
Hooker 100-inch reflector	63,458.56	
		647,990.65
DEPARTMENT OF TERRESTRIAL MAGNETISM (SEPT. 30, 1912):		
Office equipment	5,016.36	
Instruments	35,019.82	
Vessel and ocean equipment	117,212.14	
Land equipment	1,246.20	
		158,494.52
		1,818,666.69

REPORT OF AUDITOR.

WASHINGTON, D. C., *November 22, 1912.*

The Executive Committee,
Carnegie Institution of Washington, Washington, D. C.

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1911, to October 31, 1912, by authority of the Board of Trustees. We did not, however, audit the books of the various departments, as that is done by the Bursar and his associates, but we did verify the totals as carried from the subsidiary books to the general books.

The income from the Endowment Fund Investments and other sources has been duly accounted for and expenditures have been authorized and are supported by proper vouchers.

The securities representing the Endowment, Reserve, and Insurance Funds were produced to us, the cash in hand was verified by count and the cash on deposit with banks was verified by properly authenticated certificates.

Respectfully submitted,

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Vice-President.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of the American Audit Company, New York.]

Attest:
THEO. COCHEU, JR., *Secretary.*

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 27, 28). The following list has been made as complete as possible, and in some cases titles may be included which have only an indirect connection with grants from the Institution:

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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1912, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

Progress in modern botanical science necessitates the correlation of a wide range of phenomena interlocking with the activities of plants, and the development of the main researches that have been taken up by the Department has been much like the building of cantilever bridges, the farther ends of which might come to rest upon piers in chemistry, physics, geology, or geography. The chief problems of the Department have been taken to lie in the domain of phyto-chemistry, in the water-relations of plants, and in the environic reactions of organisms. The development of methods and the broader interpretation of the results have extended far into the field of conjunctive science, and have led to the consideration of some physical, biological, and meteorological subjects, not usually included within the province of botany, but which are of the greatest importance in the geographical aspects of the subject. Thus it became apparent, early in the studies of the Salton lake, that the revegetation of the beaches emersed each year varied progressively, but more widely than justified by the simple concentration of the water. Next bacteriological examinations by Dr. Brannon showed that "sulphur" bacteria found in the neighborhood of decaying submerged trees were breaking up the sulphates and that deposition of calcium as a carbonate ensued. The removal of the calcium from the water unmasked the sodium in the form of common salt in such manner that it exerted a much greater toxic action on the plants and seeds with which it came into contact.

Another generalization of importance is that of the "equation of the desert" or index of aridity, constructed on experimental and instrumental evidence by Dr. Shreve, in which the ratio of evaporating power of the air to the soil-moisture into the time $\left(\frac{E}{SM} \times T\right)$ is found to express graphically and accurately the relative aridity of any region. Thus the Desert Laboratory domain (2,300 feet) is 30 times as arid as the montane plantation (8,000 feet) in the near-by mountains.

THE CAHUILA BASIN.

THE MAKING AND DESICCATION OF SALTON LAKE.

The results obtained from the studies made by various collaborators upon the phenomena consequent upon the formation of Salton Lake in the Cahuila basin will be presented in a manuscript to be completed at the end of 1912. The combined observations of the workers engaged with this subject extend over a period of 59 years, beginning with the original discovery of the fact

* Situated at Tucson, Arizona. Grant No. 741. $37,905 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 2–10.)

that the Salton Sink lay in a basin below sea-level by Prof. William P. Blake as a member of the Williamson Expedition in 1852. The depression, which was designated Cahuila Basin by Professor Blake, was traversed by him at various times between 1853 and 1910, the year of his death. He took an active part in the observations upon the lake begun in 1906 and prepared a sketch upon "The Cahuila Basin and the Desert of the Colorado" in 1909, which will be incorporated in the volume in preparation. The sphere of activity of the other participants is indicated below.

Geography of the Colorado Delta, Pattie and Cahuila Basins, by G. Sykes.

Since 1890 Mr. Sykes has made various voyages down the Colorado River and up through minor channels of the delta, and several overland journeys across the two main basins contiguous to the delta. Some of his results have been compiled as maps published by the American Geographical Society. The alterations in the delta and the changes due to flooding of the basins are of such striking character, by reason of the rapidity with which the delta is built up and extended, that it has become important that historical records of the earlier aspects of the region should be consulted. To this end Mr. Sykes spent the greater part of the summer and autumn of 1911 at the British Museum, and in 1912 consulted the manuscripts and records in the New York Public Library, the Los Angeles Public Library, and the Bancroft collection of the University of California. The information obtained from these sources throws much light on the history of the delta and offers an explanation of the origination of the myth of the island character of the peninsula of California which prevailed in the eighteenth century. Topographical notes made during the past few years on many traverses of the region will be used in preparing a map showing the general features of the region and present status of the lake and its islands.

Composition of Salton Water, June 1912, by A. E. Vinson.

The annual sample of Salton water was taken as usual from near the surface of the lake at a point southeast of Mecca, where the greatest depth is found. The determinations of principal interest are as follows:

	Parts per 100,000.
Total solids dried at 110° C. plus water of occlusion and hydration	846.55
Sodium	270.71
Potassium	3.81
Calcium	17.28
Magnesium	13.62
Aluminum	.10
Iron	.04
Chlorine	395.44
Sulphuric, SO_4	106.83
Bicarbonic, HCO_3 (volumetrically 12.15 CO_2)	16.85
Carbonic, total CO_2 (gravimetrically 12.09 CO_2)	12.09
Silicic, SIO_4	1.79

The total solids increased about 17.5 per cent during the year ending June 3, 1912, the increase for the preceding year being 19 per cent. The calcium content of the water increased but 10.6 per cent, the difference between this and the total increase being ascribable to the action of bacteria as revealed by Dr. Brannon in the succeeding section of this report. Sodium has increased 18.9 per cent, while potassium remains stationary and does not appear in the increase of the total dissolved solids. Thus in 1908 this element was 1 part in 158 of the total solids, while it is but 1 part in 222 in 1912. The aberrant rate of variation of calcium has been shown to be due to biological agencies, but it is not certain whether purely physical reactions or organic absorption play a part in the disposal of the potassium. However, it is shown conclusively that the concentration of a body of water like the Salton Lake is not simply a matter of evaporation, crystallization, and chemical interaction.

The Surface Geology and Soils of the Salton Sink, by E. E. Free.

A general examination of the surface of the slopes of the basin has been made by Mr. E. E. Free, and analyses have been made of samples of soils which must be taken into account in the determination of the character of the run-off into the lake, and also as to the chemical and physical features offered by emersed strands around the receding lake.

Alterations in Woody Tissues and Bacterial Action in Salton Water, by M. A. Brannon.

The recession of the waters of the Salton Lake, which began in 1907, uncovered areas on which a vegetation chiefly composed of desert types was growing before the submergence. The emersed plant-remains comprised chiefly *Prosopis juliflora* D. C., *Prosopis pubescens* Benth., *Covillea tridentata* Vail, and a few specimens of *Populus deltoides* Marsh.

Stems of *Prosopis* and *Covillea* representing the emergences of every season up to and including that of 1911, as well as living material, were sent to Dr. Brannon, who was at work in the botanical laboratories of the University of Chicago in September 1911. Carboys of water were also provided for the experimental study of the action of the water. Specimens of a single kind of wood were placed in separate carboys of pure Salton Sea water and duplicate cultures were made in Lake Michigan water. These cultures were maintained at room temperature and carefully observed during a period of six months. Within two weeks after the cultures were made there was evidence of changes in the Salton Sea water and in the specimens immersed in the culture carboys. Much sulphureted hydrogen escaped from the carboys when they were opened, and the cell-walls in the region of the cambium were broken down. The processes leading to these two results advanced steadily until a static condition in the sulphates of the cultures had been established. During the transition periods large quantities of hydrogen

sulphide were liberated as the sulphates were reduced; the hydrogen sulphide was used by Beggiatoa for energy releasal and free sulphur was liberated. Small quantities of sulphuric acid were produced and united with various bases in the water. Considerable ferrous sulphide resulted from this action. Accompanying the chemical changes noted there were also well-defined modifications of the cell-walls of the stems in the region of the cambium. These resulted in the separation of the phloem and cortex sheath, which finally left portions of the woody cylinders of the immersed woods wholly exposed.

Chemical and bacteriological search for the agents of decomposition of the sulphates and the cause of hydrolysis of the walls in the cambium of the woody specimens was instituted. Chemical analyses of the water during the cultures did not reveal any free chemical in the water that could injure the tissues of the plants. Hence it was believed that the results were due to bacterial action. Such proved to be the case. In fact both the reduction of the sulphates and the hydrolysis were found to be due to the action of different groups of bacteria.

Somewhat similar but less pronounced results were obtained from the cultures of Lake Michigan water. Consequently the organisms involved in the complex chemical work of reducing sulphates, liberating hydrogen sulphide and free sulphur, and hydrolyzing pectin compounds in the young cell-walls of the cambium zone of woods are widely disseminated.

A careful study of a large number of sections of the woods which emerged annually from 1907 to 1911 did not show any breaking down of cell-walls in the regions of the xylem, pith, or rays. The cell-walls in the corresponding zones of the same species that had been submerged from one to four years had equal thickness. No evidence of mineral deposition subsequent to submergence could be found.

The conclusions drawn from the studies of the action of Salton Sea water on woody plants are:

The agents that reduce the sulphates in the Salton Sea water and liberate hydrogen sulphide and those which use the hydrogen sulphide and liberate free sulphur are members of various bacterial groups.

The agents that hydrolyze the cell-walls in the delicate embryonic regions of the cambium are formed by bacteria which belong to the *Amylobacter* group.

Evidence that petrification had begun in the tissues of the woody plants that had been submerged for four years in Salton water was not found in the sectioned woods which emerged in the years 1907, 1908, 1909, 1910, and 1911.

The Behavior of Micro-organisms in Brines, by G. J. Peirce.

The three years during the greater part of which the weekly collections and examinations have been made have presented such different weather conditions that the continued study of the micro-organisms in the brines of salt-works on the shores of San Francisco Bay has been well worth while.

The winter temperatures of air and water and the time and amounts of rain have varied rather surprisingly; the times of appearance, the distribution, and the behavior of the organisms have varied correspondingly. Whereas the behavior of an established land flora in the temperate zone varies mainly with the temperatures of air and soil, the behavior of the brine-flora under examination varies mainly with the concentration of the brine. This concentration depends principally upon two factors: the winter rainfall and the summer clearness and dryness of the air. An abundant rainfall so dilutes the sea-water with which the brine-ponds (salterns) are filled that the characteristic brine organisms are late in making their appearance in the salterns; on the other hand, they may make a more or less luxuriant growth during the winter on the surface of the heaps of salt stored in the open for shipment. Late rains, falling without much wind upon the already somewhat concentrated brines, form a shallow layer of fresh or brackish water on the surface, driving the motile organisms downward, with great mortality, and delaying their reappearance on the surface until diffusion and evaporation have made a fairly homogeneous brine once more.

As the brine is not clear, the absorption of light is very great, and the photosynthetic activities of the chlorophyll-containing organisms are correspondingly interfered with. It would be interesting to know the relative depths to which diffused and direct sunlight and its component rays penetrate these and other waters; for obviously these factors also must greatly affect the behavior of the independent organisms inhabiting fresh and salt waters. Unfortunately the photometry of colored lights has not yet reached a stage in which it can be applied to a study of these organisms.

Although these brines are rich in organic matter, the difficulties of inorganic analysis are so great that it has been impossible to secure an organic analysis. Many of the brine organisms are more or less completely saprophytic, but it has been impossible to determine their relations to the organic components of the brines. The usual technique of physics, chemistry, and biology is not adequate for a satisfactory treatment of these extraordinary organisms, living under what may be called fatal conditions.

The Floral Elements of the Salton Region, by S. B. Parish.

A brief study of the vegetation of the Salton Sink has been made by Mr. Parish in order to determine the biological setting of the newly formed lake. This work has been extended to take into account the species which have been introduced by the agricultural operations in the southern part of the basin. Details have been obtained as to the species which have come into the basin by the current of the Colorado River, and some of the main features of dissemination of the forms which would be competitors for the occupation of the emersed lands have been ascertained.

Movements of Vegetation Due to Submersion and Desiccation of Areas in Arid Regions, by D. T. MacDougal.

The observations and experiments upon the occupation of the strands, uncovered by an average yearly recession of about 50 inches, have now been carried through six years. Strips as wide as 1,400 feet have been laid bare on the shores with gentlest gradient, while on precipitous slopes the strand is less than a dozen feet. The amount of soluble material in the lake water has increased from 0.33 per cent to nearly 0.9 per cent, so that a series of beaches is present five, four, three, two, and one year old, each left saturated with the lake solution of the year of its emergence and showing stages of occupation correspondent with this condition of the substratum and with its age. The hilltops emersed as islands offer evidence of the most vivid interest as to the means by which plants are carried across barriers to distant unoccupied areas. One new line of observation was made by motor from Mecca southward along the western side of the lake to the cultivated lands along the New River in June, while the islands were visited by a launch late in the year.

VARIOUS INVESTIGATIONS.

Physical and Botanical Features of Sudanese and Libyan Deserts, by D. T. MacDougal and G. Sykes.

In accordance with plans perfected early in 1911, Mr. G. Sykes proceeded to London, and in addition to carrying on some bibliographical work in the British Museum, preliminary arrangements were made for an examination of the region between the Red Sea and the forks of the Nile, and of the Libyan Desert to the westward of the lower Nile. The members of the expedition proceeded to Cairo via Brindisi and Port Said early in January. Port Sudan, on the Red Sea, was reached by steamer from Suez in mid-January, and after a brief inspection of the short coastal slopes of the mountains, which rise to an elevation of over 5,000 feet, a special car, accommodating three persons, and which would serve as a moving laboratory, was chartered for the trip from the coast to the Nile at Atbara and southward to Khartum. This plan gave opportunities for observations at Sal Lom, Kamobsana, Sinkat, Talgwareb, and Atbara, in the eastern desert, and it was possible to gain a comprehension of the principal features of this arid region within a comparatively brief time.

The slopes toward the Red Sea offer many of the surface features characteristic of the arid regions of Arizona and Sonora. The streams sink into the loose débris which fills the "khors," or washes, making an underflow, the possibilities of which have hardly been tested by those who are occupied with plans for agricultural development. The vegetation comprises a large number of species, in which the euphorbias and aloes comprise the succulents so strongly represented by the cacti in America.

Caravan resting in Ascent from Baharia Basin, Libyan Desert.

The slopes toward the Nile are much longer and the underflow runs more deeply amid the coarse material in the "khors," while the desert grasses and spinose types are the most prominent constituents of the vegetation. The entire region is one which offers about the same problems in colonization as portions of Mexico and southwestern United States.

Work in the Libyan Desert was carried out chiefly by means of a camel caravan. The party proceeded by rail to the Merkez of the Western Egypt Development Company, in the oasis of Kharga, about 120 miles west of the Nile, early in February. A dozen camels had been selected for transport and riding animals were secured, and Abu Salem, a well-known sheik, acted as caravan leader. The route carried the party to the oasis of Dakhla, thence northward to the oasis of Farafra, thence northeastward to the oasis of Baharia, and back to the Nile at Samalayut and Minia, where the caravan was discharged. The total distance traversed by the caravan was about 500 miles, which was done at the average rate of 25 miles per day.

The Libyan Desert offers highly characteristic physical features, which are duplicated in part only in other deserts, and are unexpectedly in contrast with arid regions in the Sahara in southern Algeria examined by Dr. W. A. Cannon and Prof. Hans Fitting.

The water in the Libyan Desert is either plutonic or is derived from catchment areas so widely distant that the supply is independent of local climatic conditions outside of evaporation. The exclusively eolian erosion, with the resultant rounded hills, "sogag," "karafesh," and great sand ribbons hundreds of miles in length, gives a landscape widely different from those in which precipitation plays a part. The vagrant rainstorms furnish an uncertain supply of moisture which supports some vegetation in the dune areas and among creviced rocks. Distances as great as 40 miles were traversed without encountering a single plant, dead or alive. Lizards, beetles, rodents, birds, and gazelles were seen in places widely separated from sources of water, and must have depended upon the scanty proportion of moisture in their food. The quantity of water consumed by men and animals seemed to be less than that necessary in American deserts, while "sunburning" and other physiological effects of light and heat were greater. The total evaporation at some places in the eastern part of this region and in the Red Sea Province has been found to amount to over 200 inches yearly, or about double the amount measured in an American locality, although observations of this matter have not been made in the driest regions in either desert.

Only climatic changes of great amplitude would leave enduring records in the Libyan Desert. Remains of habitations and extended cultivation would, in most cases, depend upon engineering enterprise and efficiency in irrigation. The present size of the oases might be increased by a unified control of the water supply, and it seems highly probable that exploratory borings might tap new supplies which would serve in the formation of new oases.

The detailed results of the field studies are now being prepared for publication.

Botanical Features of the Algerian Sahara, by W. A. Cannon.

The observations of Dr. Cannon on the plants and conditions of plant life in southern Algeria, which were made in 1910-11, have been compiled, and the leading results may be summarized as follows:

Algeria is divided into three climatic provinces which correspond to the main topographical divisions. These are the Tell, the High Plateau, and the desert. The climate of the former is coastal and that of the latter continental, while the High Plateau, a semi-arid region, has a climate partaking of the characteristics of both of the other regions. The rainfall of Algeria decreases as the distance from the coast increases, until from a maximum of about 1 meter on the littoral it becomes 100 mm. and less, and on the desert it frequently happens that no precipitation whatever occurs for many months. The relative humidity with a mean of 85 per cent at Fort National, near the coast, sinks to a mean of 42.6 per cent at In Salah, 600 miles from the Mediterranean. At Algiers the evaporation is 1,654 mm. and at Ghardaia, 400 miles from the coast, it is 5,309 mm. At the latter place the average evaporation is 46.5 times the average precipitation. The great aridity at Ghardaia is the more apparent when it is considered that the evaporation-rainfall ratio for Yuma, Arizona, is 35.2.

The annual and diurnal range in temperature on the desert is great, although the records consulted possibly do not give the maximum range. The greatest annual range given for southern Algeria is 57.0° C. (Ghardaia). A diurnal range of 24.7° C. was observed between 3 p. m. and 6 a. m. in the open desert in November. The maximum yearly temperature given in the records consulted was 52° C. at Ouargla. Freezing temperatures are experienced probably every winter on the desert.

The portion of the Algerian Sahara visited has great topographical diversity. Beginning at Laghouat, at the southern base of the Saharan Atlas, the main regions visited were as follows: The region of the Daya is rolling and contains many small basins (dayas without surface drainage). Here the surface of the ground is covered with pebbles and small rocks, and the soil is shallow except in the "dayas" themselves, where it is very deep. A hardpan (caliche) extends nearly to the surface on the plain of the daya region. The plains are covered with a sparse vegetation, including some trees. South of the region of the daya is that of the Chebka, where the low, flat-topped mountains cross the country in a confused manner, but where watercourses ("oueds") occur. As the southern portion of the Chekba is reached, the plains between the mountains broaden rapidly until they constitute the main topographical feature. Ghardaia is on the edge of the Chebka, and the important Oued M'Zab separated this region from the Gantara, which is the "hamada," or stony desert. Towards the eastern side of the Gantara are extensive "chotts," or saline areas. At Ouargla the flood-plain of the Oued Igharghar, over 750 miles in length, is reached; this is the alluvial or "reg" desert. Between Ouargla and Touggourt and to the north of Touggourt there is much sand (the "areg" desert). South of

Biskra a wide monotonous plain, probably "reg," separates the great Chott Melghir from Biskra and the southeastern extension of the Atlas.

Gypsum occurs in large quantity in the immediate vicinity of Laghouat. The plains throughout southern Algeria are rather shallowly covered with a dark adobe-like soil with an admixture of pebbles and large stones. In the slight drainage depressions the proportion of fine soil is less than on the higher areas. Comparatively little sand was encountered, although at a large chott west of Ouargla dunes 150 meters in height were seen. On the flood-plains and in the floors of the dayas the soil is of a depth sufficient for extensive root development, but on the plains this is not the case. A determination of the water-content of soil taken at a depth of 10 to 15 cm. on the plain near Ghardaia showed 0.8 per cent water. Through the kindness of the Bureau of Soils, U. S. Department of Agriculture, the critical moisture-content of the same soil was determined to be about 5 per cent. As a comparison it may be stated that the critical moisture-content of mesa soil taken from the domain of the Desert Laboratory was 10.5 per cent.

The vegetation of southern Algeria reflects the extreme aridity of the region. Plants with a water-balance are almost wanting, and there are no trees outside of the oases and dayas. The flood-plains of the oueds support a comparatively fairly abundant vegetation, which is characterized by great reduction of leaves. Plants are rare on the plains, and certain portions of the plains (gantara) between Ghardaia and Ouargla are quite barren.

Although the plains appear wholly void of vegetation, careful examination often reveals from 300 to 400 on an area 16 by 15 meters, a paradoxical condition due to the dwarfing effects of the arid climate.

The vegetation is subject to the ravages of herbivorous animals, wild as well as domestic, to a degree possibly not equaled in any other region, although probably no species have become extinct from this cause. Many plants are left untouched because they are distasteful, poisonous, or well armed, and one example of total dependence of an unarmed species on a species which was armed was observed.

The delicate response of perennials to slight environmental changes was seen at Ghardaia, where many perennials were forming new shoots at a time when relatively better moisture conditions were brought about by a lower temperature; no rain had fallen for over 12 months.

The root-systems of the plants of southern Algeria are not so diverse as in the Arizona forms. There are but two well-marked types, namely, those with a well-developed tap-root and those with roots that are generalized. The former is the type of plants which are confined to the flood-plains of the oueds, or where the soil is deep. Plants with roots which may extend far horizontally and which penetrate deeply are found on the plain and also in the oueds. The superficially placed type of root-system, which is typical of fleshy plants, especially of the cacti, is not represented. Should the cacti, for example, have a deeply penetrating type of root-system, their range into arid regions would probably be greatly extended.

Depth of Water Table as a Factor Limiting Distribution of Trees, by W. A. Cannon.

Preliminary comparison of the depth of the water-table and the distribution of the mesquite (*Prosopis*) indicates that the relation is probably an important one. As shown in another place (The Root Habits of Desert Plants, by W. A. Cannon, Carnegie Institution of Washington Publication No. 131), the habit of the mesquite, both that of the root and the shoot, is a very variable one. The shoot may be either a tree with a marked bole or a true shrub with several short stems. The latter is characteristic of relatively arid habitats, while the former has been found to indicate a water-table so close to the surface as to be attainable by plant's roots. A survey of a limited area shows that where the species has the arboreal habit the water-table does not usually lie deeper than 40 feet. In this area the soil is granitic sand with an admixture of adobe clay. In areas adjacent to those thus inhabited by the mesquite, but where the depth to the water-table is greater, the species assumes the shrub habit. Observations in other regions indicate that the root-water-table relation, to a certain degree and under certain conditions, may be of importance in determining the presence or absence of trees and probably of forests.

The Precise Evaluation of Rainfall Records, by Forrest Shreve.

Studies have been inaugurated looking toward a more precise evaluation of records of desert rainfall in relation to vegetation, a subject of great practical importance in its bearing on the principles of dry farming. The moisture-content of a heavy clay soil—conservative in its moisture changes—has been determined at three depths during a period of 12 months, and the resulting data have been analyzed with respect to the influence of individual falls of rain in restoring the supplies of soil-moisture. It has become possible to state the approximate limits of rainfall which is too slight to affect the soil-moisture and the limit of falls which are so great as to produce a run-off and no further increase of the soil supplies. The effect of the same amount of rain is found to be different in the summer and in the winter rainy seasons, due to differences in the rate of surface evaporation, and is found to vary in relation to the pre-existing moistness of the soil. The installation of an electrical recording rain-gage at the Desert Laboratory and the development of improved methods of securing samples of soil for moisture determination have given facilities for a continuation of this work along more exact lines.

Vital Statistics of Desert Plants, by Forrest Shreve.

The work on vital statistics of desert plants has been continued on an observational area for which a full record of germinations and deaths for three years is now at hand. The restriction of all natural germinations of desert perennials to a period of two weeks at the opening of the summer

rainy season has alone made possible the recording of all new individuals and has betrayed large differences in the number of germinations from year to year. These differences are not in accord with the seed-crops of the years in question and will require further investigation. The record of the soil-moisture conditions has been used in this work, so that it is now possible to correlate the rates of seedling mortality in different seasons with the changing soil-moisture content.

Influence of Cold-air Drainage on Distribution, by Forrest Shreve.

A comparison of the minimum-temperature records for the Desert Laboratory and the Breeding Laboratory, which are respectively situated on Tumamoc Hill and in the Santa Cruz Valley at its base, together with the comparison of data from several stations in the Santa Catalina Mountains differing in elevation and in topographical situation, has given fresh data as to the importance of cold-air drainage as a factor determining plant occurrence. Gradients of temperature change with altitude have been worked out separately for ridges and valley bottoms, showing that these topographic features, when situated at the same altitude, have minimum-temperature conditions which are as different as those of two ridges or of two valleys which are 2,000 vertical feet apart.

The Soil-moisture Evaporation Index and Its Relation to Vegetation, by Forrest Shreve.

The observations and instrumentation carried on in the Santa Catalina Mountains, mainly in the summers of 1910 and 1911, have been collated and are in preparation for publication. The leading features of this work have been the determination of the general facts of plant distribution in relation to altitude and topography, the securing of instrumental measurements of the physical factors which seemed to be of chief weight in relation to the vegetation, and the subsequent correlation of these two bodies of data.

The vegetation of the Santa Catalina Mountains presents three well-marked belts or altitudinal regions—desert, chaparral, and forest. The vertical limits of these belts, like those of the component species, are about 1,000 feet higher on south-facing than on north-facing slopes. The six stations for instrumentation were situated at vertical intervals of 1,000 feet, two being located in each of the vegetational belts. The data from the six stations have been expressed in the form of gradients, which show the relation of altitude to the changes of the several factors. Interest has centered largely in this work in the gradients of rainfall, soil-moisture, humidity, and evaporation. The rainfall at the forested altitudes is from three to four times as great as that of the desert, yet the protracted drought periods of the desert are of equal length in the two regions. In the forested region a large portion of the principal annual drought period precedes the opening of the growing season, and its force is lessened by this as well as by other fac-

tors. During the principal drought period—the arid fore-summer—the soil-moisture falls to as low a figure in the desert and chaparral belts as in the desert plain itself, while in the forested belt the surface moistures are nearly as low. The vertical gradient of evaporation indicates that it falls to approximately one-third as much at the forested altitudes as on the desert, a ratio which holds equally for the high evaporation rates of the arid fore-summer and the lower ones of the humid mid-summer.

The ratio of soil-moisture supply (*SM*) to the evaporating power of the air (*E*) is a measure of the conditions which determine the maintenance of the absorption-transpiration balance of the plants. It has been possible, from the data in hand, to determine the ratio of these factors for the several altitudes of the Santa Catalinas. The conditions indicated by these ratios are operative for a length of time (*T*) which diminishes with altitude, a fact which may be incorporated in the ratios by using as a factor the number of weeks from the opening of the growing season to the close of the arid fore-summer. The sets of ratios thus obtained are shown in the table herewith.

Feet.	$\frac{E}{SM}$	$\frac{E}{SM} \times T$
3,000	9.7	29.1
4,000	7.7	18.6
5,000	7.5	15.0
6,000	7.8	12.5
7,000	4.7	6.1
8,000	1.0	1.0

The set of ratios which involve the time factor are a graphic index of the relative aridity of the several altitudes and indicate that the desert conditions are nearly 30 times as severe as those of the forested mountains at 8,000 feet. A comparison of these ratios as worked out for north-facing and south-facing slopes at the six stations indicates that the conditions of which the ratios are an expression are chiefly responsible for the differences in the vertical limits of desert, chaparral, and forest on opposite slopes. The ratio of soil-moisture to evaporation appears, therefore, to be the chief compound factor determining the extension of forest and chaparral and their limitation at the edges of the desert.

Water-relations of Plants, by B. E. Livingston.

Prof. B. E. Livingston has continued his studies on the physics of the water-relations of plants and the relations which obtain between organism and environment in this regard. Studies of the aërial water-relations of plants have, during the last year, added several new and apparently important points in this field, as well as several refinements and improvements in the methods of measurement and integration of the evaporating power of the air. These methods—depending largely upon atmometry—have now been generally adopted and are proving themselves valuable, not only in physiological and ecological researches with plants, but also with animals.

The preliminary investigation of the conditions of soil and air which determine the wilting of plants, carried out in the summer of 1910, with the assistance of Dr. William H. Brown, has now been published by Dr. Brown, and the same line of study was carried much farther in the experimental

work of the summer of 1911, with the assistance of Mr. J. S. Caldwell, whose results will shortly appear. Attention is now being given mainly to the physics of the subterranean moisture conditions, with the hope that methods may eventually be devised by which these may perhaps come to rest upon a quantitative basis somewhat similar to that upon which our knowledge of the aërial water relations is now based. In this new phase of the work Mr. E. M. Harvey has assisted.

The Water-relations of Sclerophylls and Similar Ecological Types, by F. E. Lloyd.

During the month of July 1912 the march of transpiration for a series of plant pieces in duplicate was determined in continuation of work begun in 1911. The rates of evaporation were determined simultaneously, and the plant material used will be further studied in order to obtain anatomical facts with which it is desired to correlate the transpiration data. The expression "stomatal surface" will be redefined, and the transpiration rates expressed relative to this. It is hoped in this way to obtain a method of comparing the leaf mechanisms which will give an adequate idea of the comparative behavior of the various types of sclerophylls. It is evident from the character of the curves expressing the march of transpiration that the behavior of a given species is specific, and different, under the same conditions, from that of another species.

It has also emerged from the determination of the march of transpiration, and *pari passu* of the rates of growth in *Eriogonum nudum,* that the rate of transpiration and that of growth stand in an inverse relation to each other, growth being checked by incipient "drying," and being stopped altogether when wilting sets in, which indeed frequently causes shrinkage of the tissues to an extent sufficient, it may be, to cause death by drying.

Physical Relations of Roots to Soil Factors, by W. A. Cannon.

The field studies on the root-systems of the desert plants which have been carried on by Dr. Cannon have revealed many problems requiring experimental treatment by special methods. As an introduction to such studies the general problem of the placing of the root-systems was first selected for attempted solution. To this end it was decided to study the plants growing in soil cultures and to subject them to various conditions, especially concerning moisture and aëration. A special form of air-pump was constructed for the study of the air-relation, by which a known amount of air, either constant or variable as desired, can be passed through the soil in use. This apparatus gives at the same time a relative measure of the porosity of the soil used, either as dry or for any percentage of contained moisture. As a check on the results obtained in this fashion, the relative porosity of the soils employed was learned through the use of a mercury manometer by which the height of the water-column, as well as the rate of the ascent of

water, may be determined. This apparatus is a modification of the method commonly in use for the determination of the same factors, but is a shorter as well as a more convenient one. The special form of receptacle employed in the cultures permits the observation of the rate of the growth of the roots, and the use of air either dry or moist, as well as the application of heat or cold as desired. In addition to these pieces of apparatus a clinostat for carrying duplicate cultures weighing 70 pounds or more was also designed.

A few preliminary experiments indicate that the roots of such plants as the mesquite (*Prosopis*) and the ocotillo (*Fouqueria*), the former with a variable root-system, which may or may not penetrate deeply, and the latter with a root-system relatively shallowly placed and with little variation, have unequal responses to the air-relation. Under similar conditions of aëration the roots of the mesquite grow more rapidly than those of the ocotillo. The rate of growth of the latter in particular, as well as the richness of branching, is directly associated with aëration. When an excessive amount of air is presented to the roots, however, retardation of growth takes place. The results of similar experiments on mesophytes indicate that increased aëration, within limits, favors root-growth and shoot development. Roots appear to grow equally well in sterilized and in unsterilized soil, under similar conditions of aëration. In unsterilized soil, however, soil organisms develop more rapidly with artificial aëration than without, but the position occupied by them in the soil appears to coincide with the extension of the root-system.

Structural Relations in Xenoparasitism, by W. A. Cannon.

Artificial parasitism has been induced in several species by Dr. D. T. MacDougal, who has reported on them from time to time (Carnegie Institution of Washington Publication 129). Among the nutritive couples, and one of the most successful, was that of the Mexican grape (*Cissus digitata*), which was induced to form roots and a shoot with leaves and tendrils when attached to a flat-stemmed opuntia. The structural relations of the parasite and host in this nutritive couple have been investigated by Dr. Cannon.

The xenoparasite-organized roots within the tissues of the host totaled over 7.5 cm. in length, all of which at first was capable of absorbing nutriment from the host. The older portions of the root, however, were found to have organized a layer of cork. The portions of the host adjacent to the fresh-growing parasitic roots were of unmodified parenchymatous tissue, but wound-tissue is soon formed, so that the living cells of the host and those of the parasite are ultimately separated from each other by non-living tissue of considerable thickness. When the latter is the condition, diffusion from host to parasite would take place very slowly, if at all.

The character of the responses of the root to the host is suggestive of possible changes occurring in the initial steps of parasitism of habitual parasites. In the xenoparasite root-hairs were not formed, indicating that atrophies of different root-organs are among the first structural changes to

be expected. After penetration has been accomplished the further structural modifications of the parasite occur in direct response to the physiological activities of the particular tissues of the host. From the latter the second condition is met, namely, a delayed definitive development of the tissues of the parasite, and great plasticity by which parenchymatous tissues might be modified in many ways toward perfected morphological articulation with the host.

The Determination of Leaf-temperatures, by Edith B. Shreve.

A special form of calorimeter containing turpentine was designed for the purpose of testing the temperatures of leaves. The cup is of thin brass, nickeled and polished, and the jacket is a silvered Dewar vacuum beaker. The cup is suspended near the bottom of the jacket in a wooden ring and is closed by a cover of wood perforated for a thermometer and a stirrer. The opening in the jacket is closed by a plug of cotton wool. When leaves were placed in the turpentine of the calorimeter their temperatures were found by the reduction of the formula $A\ (Sa)\ (Ta - Tc) = B\ (Tc - Tb) + C$, in which A = weight of leaves, B = weight of turpentine, Sa = specific heat of leaves, Sb = specific heat of turpentine, Ta = original temperature of leaves, Tb = original temperature of turpentine, Tc = final temperature of the mixture, and C is the amount of heat absorbed by the containing vessel. The substitution of known or ascertainable quantities allows the ready calculation of the original temperature of the leaves to within 0.2° F.

Autonomic Movements of Cylindrical Stems of Opuntia, by Edith B. Shreve.

The inception, duration, and character of the movements of maturing stems of *Opuntia* discovered by Dr. D. T. MacDougal in 1909 was studied by observations and experiments with plantlets of *Opuntia versicolor* under control conditions and in the open. These movements ensue in young plants 20 to 60 cm. in height with such amplitude that the tips of the stems are carried through an arc extending from the ground on one side of the stem over to a similar position on the opposite side. Movements of a similar kind are exhibited by branches of large plants which result in placing these members in a final position much different from the original one. The movement is influenced by light, but its mechanism has not yet been made out.

Chemical Effects of Radiant Energy in Plant Processes, by H. A. Spoehr.

Further studies with ultra-violet light have shown that, contrary to the statements of Usher and Priestly, carbon dioxide, either in gaseous form or when dissolved in water, is not reduced to formaldehyde when exposed to these rays. However, it has been found that formaldehyde is formed when a solution of potassium carbonate containing colloidal platinum and through which carbon dioxide is allowed to pass is exposed to ultra-violet light. The failure to get a reduction of carbon dioxide in the presence of nascent hydrogen, when this is produced electrolytically, disproves the theory of Stok-

lasa as to the function of nascent hydrogen produced by enzymases in the plant-leaf. Stoklasa's experiments can only be explained to the effect that the metallic hydroxides formed in his method of obtaining hydrogen play the same rôle as the colloidal platinum in the experiments mentioned above. This discovery is another step in the substantiation of the theory previously put forward. Whether formic acid is an intermediate step in the photosynthesis process or whether its presence is due to subsequent oxidation of formaldehyde has not been definitely established. While formaldehyde has been obtained through the action of light from a great many of the acids found in the leaf, conditions under which formic acid yields this reduction product have not been discovered.

A number of plant acids, under various conditions of solution, have been exposed to the sunlight for an entire year. The products formed by this long insolation are now being investigated.

Thus far it has been found that acetic, glycollic, propionic, malic, tartaric, and citric acids are decomposed in the light with the liberation of considerable quantities of carbon dioxide. Formaldehyde is also formed, and, in the case of the higher hydroxy-acids, non-volatile substances, which reduce Fehling's solution. It will be of special interest to determine what these latter substances are and whether they are bodies from which sugars can be formed. In general all these acids are decomposed very much more easily in the form of a salt than as the free acid. It is noteworthy that formic acid yields no reduction product. Indicative of the high energy content of the sunlight is the fact that acetic acid, one of the most stable organic compounds, is decomposed.

This study has been undertaken in order to determine the function and fate of the organic acids in the succulents in particular, and what rôle these substances play in the photosynthetic process in general.

Micro-chemical studies have been begun on isolated chloroplasts. Using *Helianthus* and *Tradescantia,* methods have been found which will permit the observation of the photosynthetic action of isolated chloroplasts for several hours. Pure cultures of *Proteus vulgaris* have been used for the detection of oxygen liberated by the chloroplasts. The object of the investigation is to establish the conditions of solution most favorable to the living chloroplasts and to the photosynthetic processes, and, if possible, to follow the latter micro-chemically.

During the year daily light measurements have been made at the Desert Laboratory. The catalytic action of uranium acetate on oxalic acid induced by light is particularly sensitive to the violet end of the spectrum, and accordingly this method was employed. Observations with a Smithsonian Institution pyrheliometer have been made at the same time. During the month of June concomitant measurements were made at the Desert Laboratory and on Mount Lemmon, 20 miles to the northward. It was found that while the differences observed with the pyrheliometer were very slight, the

blue rays are more intense at the Desert Laboratory (2,700 feet) than on Mount Lemmon (9,000 feet).

Acidity, Gaseous Interchange, and Respiration of Cacti, by H. M. Richards.

In continuation of the investigation on the respiration of cacti and of the phenomena related thereto, a considerable number of series of determinations of carbon-dioxide evolution by *Opuntia versicolor* under various external conditions were made during the winter of 1911–12 in New York, and exclusive attention was given to this work at Tucson, July and August 1912.

The effects of temperature changes were studied somewhat extensively. At temperatures above 50° C. the respiration curve falls rapidly and the maximum appears to lie between 45° and 50° C. At low temperatures, in the neighborhood of 10° C., the CO_2 evolution almost ceases. The range from 10° to 50° C., while great, is not far from that to which the plant might be subjected during the year. The daily course of respiration under temperature conditions representing an average Tucson day of the late spring was determined at hourly intervals over the whole 24 hours. The most interesting fact which developed was the *lag* in response to temperature changes. This amounts to about an hour both at the maximum and minimum. Other experiments were also tried to further establish this and, as might be expected, it was found that where a considerable change, say of 10°, was made suddenly the lag in response was greater than in the cases cited above where the rise or fall had been gradual.

As a check on all the respiration determinations the wound reaction was studied, since it is necessary to mutilate the plants to the extent of separating the joints. There is no appreciable increase in CO_2 evolution until the wounding has been considerable, as when the joints are slit lengthwise or cut into five or six pieces transversely. In such cases the usual traumatic response is to be noted. The maximum is attained about 24 hours after wounding and subsequently the respiration returns to approximately the normal in about 3 to 3½ days. No appreciable increase follows the mere breaking of the joints apart, certainly not when the small wound surfaces were properly protected with clay or vaseline. Intramolecular respiration in atmospheres of both pure hydrogen and pure nitrogen is considerable and at low temperatures practically the equivalent of the normal evolution of CO_2.

Coincident and parallel with these experiments, series were run for the determination of the $\frac{CO_2}{O_2}$ equivalent. The work in gas interchange was done by Miss M. E. Latham, both in New York and Tucson. Not all of the very considerable data gathered have been reduced; but the calculations show that there is an increased oxygen consumption in comparison with carbon-dioxide evolution as the temperature decreases. At 40° C. it is more nearly $\frac{1}{1}$, but below 20° C. the carbon-dioxide evolution rapidly decreases while the oxygen consumption remains nearly stationary.

As the period at Tucson comprised the end of the dry fore-summer and the subsequent rainy season, a very favorable opportunity presented itself to study the activity of the young joints which in *Opuntia versicolor* are found at this time. Consequently especial attention was paid to a comparison of the behavior of the young tissue and the mature joints of the previous year. It was also possible during late June and early July to compare the condition of mature joints which were turgid and others in an inactive state.

In general, the respiration of the young joints is far higher than that of the older but also turgid tissue, while that of the latter greatly exceeds the respiration of the mature but inactive plant.

Corresponding to the respiration activity there is a marked difference in acidity. That of the young joints is high, in some cases 1 c.c. of pure juice being the equivalent of 1.75 decinormal alkali, though usually between 1.4 and 1.5. The acidity of the old dry joints ranged from a third to a fifth of the above, while that of the mature turgid joints, which varies considerably, occupied a middle place. The range of acidity at different times in the day was enormous in the young tissue, in some cases falling in the late afternoon to nearly a tenth of that in the morning. With the fall in acidity there is a corresponding fall in respiration, most marked, of course, in the young joints where the acidity range is greatest.

In the gas interchange there is also a difference between the young and old shoots, the younger ones approximating more nearly the usual absorption of oxygen and evolution of carbon dioxide, while the older joints show the larger use of oxygen, characteristic of succulent plants. The acidity increases in the absence of oxygen and decreases very greatly with an increased supply in the atmosphere.

The experiments during the summer seem to show very conclusively that the diminishing acidity from early morning to late afternoon is a combined temperature and light reaction. In joints kept in the dark a fall in high acidity at high temperatures and a rise from low acidity at low temperatures was repeatedly obtained. On the other hand, a decrease in acidity in plants kept at moderate temperatures (about 15° C.) but exposed to the brightest illumination possible was noted in comparison with a practically stationary acidity of similar material, also kept cool, but in diffuse light. This latter observation is in keeping with results obtained by Dr. Spoehr as to the effect of sunlight on the hydroxy-acid.

With every precaution taken to obviate contamination of the results by wound respiration or possible foreign organisms, a decided evolution of carbon dioxide at temperatures above 30° C. was obtained, even when the joints were exposed to the direct rays of the sun as filtered through a layer of water and the walls of the glass container.

Opuntia versicolor was used; in the major part of the work other cacti with *O. discata, O. blakeana, O. leptocaulis,* and *Mamillaria grahami* were employed to some extent, both in the respiration experiments and in those on gas interchange.

The Relationships and Distribution of the Cactaceæ, by N. L. Britton and J. N. Rose.

A project for a comprehensive study of the cacti was organized early in the year, and plans were made for the preparation of a series of illustrated volumes dealing with the taxonomic, geographic, and economic features of these highly specialized forms.

Dr. N. L. Britton, director-in-chief of the New York Botanical Garden, and Dr. J. N. Rose, of the Smithsonian Institution, were appointed Research Associates and put in charge of this research. Dr. Britton places the entire collections of the New York Botanical Garden (with the authority of its Board of Managers) at the disposal of the Carnegie Institution of Washington for purposes of study, and will give as much of his time as possible to the research; while Dr. Rose will devote all of his time to it, and will have full access to all the Government collections. Working quarters for him have been provided in the Smithsonian Institution by the courtesy of the Secretary.

Dr. Rose was authorized to inspect the larger collections in Europe in order to ascertain what material would be available for this study in the living condition, a matter of great importance with respect to these succulents. Three of the collections visited deserve special mention: First, that of the Royal Gardens at Kew. Here has been brought together a very large collection of living succulents from America, while in the herbarium many important specimens are preserved, including some types, and especially most of the material, from which the beautiful colored plates that have appeared from time to time in Curtis's Botanical Magazine were drawn. Second, that of the Königlicher Botanischer Garten near Berlin. At this garden Dr. Karl Schumann wrote his monograph of the Cactaceæ, and here is preserved much of his material. Third, that of the late Sir Thomas Hanbury, at La Mortola. This collection is undoubtedly the finest in the world. The garden is situated in Italy, just beyond the French line, in the most beautiful part of the Riviera, where in this balmy climate these plants grow in the open often as well as, or better than, in their native habitats. Mr. Alwin Berger, curator of the garden, has offered liberal opportunities for the study of this collection and has already sent one large consignment of living plants to America.

Definite plans for field work have been inaugurated, the first of which will probably be an exploration of the West Indies and the north coast of South America, and this work, it is hoped, will be begun in the early part of the next calendar year. This will probably be followed by thorough exploration of the deserts of Argentina, South America.

Much material is being sent in by volunteer collectors and botanists throughout the Southwest, and up to the present time some twenty Government explorers are sending in specimens as opportunity permits. Although the combined cactus collections of Washington and New York are by far the

richest in the world, yet much material is needed before a reasonably complete representation of the family can be presented. For the next two or three years considerable time must be devoted to the task of collecting material and organizing the collections. In the meantime, the work of describing and illustrating the better-known species will be carried on, and a fairly good beginning has been made.

Especial attention has been given by both Research Associates to the two subfamilies Pereskioideæ and Opuntioideæ, looking forward to the publication of the volume dealing with those groups as the first of the series to be issued.

Fruit Development in the Cactaceæ, by D. S. Johnson.

Dr. Johnson has undertaken a study of the morphological and physiological features of the fruits of some of the cacti of the Tucson region which present certain features of great importance in the phylogeny and habit of these desert plants. During April, May, and June field studies were made at the Desert Laboratory of a number of species and a fine series of morphological material was accumulated to supplement the observations and experimental results. Chief attention was paid to *Opuntia fulgida,* which matures great numbers of greenish pear-shaped fruits with apparently perfect seeds. No seedlings have ever been found, however. The flowers open in May. The fruits attain their mature size (20 by 30 mm.) in late summer. Some of the fruits have only shriveled rudiments of ovules within, while others have from a few to a hundred or more well-developed seeds with curved, starch-filled embryos. The most interesting characteristic of these fruits is their persistence on the parent plant for 10 or 12 or perhaps for 15 or 20 years. During this time the fruits continue to grow until they may become 40 mm. in diameter and 70 or 75 mm. in length. This growth is due chiefly to the activity of the general parenchyma, though the vascular bundles increase six or eight times in cross-section area by the activity of the persistent fascicular cambium. Cork is formed at and near the 15 to 40 leaf-scars and over the top of the fruit.

From a few or from as many as 15 or 20 of the dormant axillary buds of this persistent fruit new flowers and then persistent fruits may arise in succeeding years. These newly formed fruits behave in like manner, so that in 10 or 12 years a parent fruit may have a cluster of scores or even hundreds of daughter fruits depending from it. No evidence was found that the seeds of these fruits ever germinate, though the seeds and their starch-filled embryos remain apparently unchanged. Scores of very young plants were examined and all were found to be evidently derived not from seeds, but by the formation of roots and shoots from the dormant buds of fallen fruits or vegetative joints.

Some attention was paid incidentally to the color characters of *Opuntia versicolor,* which shows a range from deep red to bright yellow within the

species, although the range of variability on any one plant is very narrow. Furthermore, the color of the flowers of any individual is also constant from one season to another. The differences seem to rest upon the degree to which the deep red, always manifest in the apical portions of the petals, overspreads the remainder of the flower. Similar relations prevail in the stems. The color types are correlated with differences in structure of flowers, fruits, and stems. Nothing is known as to the physiological characters accompanying these differences. The heredity of the various color-types has not been tested, and this and other species of similar composition present some very unusual genetic features.

Some Relations between Halophytes and Saline Soils, by W. A. Cannon.

Studies carried on in 1905 on the relation between halophytes and the saline soils in which they habitually grow showed that the amount of soluble salts in the species studied is characteristic of the species, and that individual plants with the greatest amount of soluble salts grow in the portion of the saline area where the salts are also most abundant. Soil analyses by the Bureau of Soils, U. S. Department of Agriculture, showed that sodium is an important element in saline soils, and that calcium (and magnesium) are present in very small amounts. Plant analyses carried out under the direction of Prof. W. G. Gies, Columbia University, showed that the amount of sodium varied in each of the species studied, being most in the species which live in the soil where the element is present also in the greatest amount.

A comparison of the relative amounts of sodium and calcium in the plants of humid regions with the amounts in the salt plants shows that where the one element is present in large percentage the other element is to be found in small amount, and *vice versa,* the two elements being thus to a degree mutually exclusive.

It is suggested that the theory of antagonism of elements as presented by Osterhout (The Permeability of Protoplasm to Ions and the Theory of Antagonism, Science, n. s., vol. 35, 1912) may form an explanation of the relation of the two elements as given above.

Inductive Effect of Climatic Complexes upon Organisms, by D. T. MacDougal.

The cultures of a number of species of plants at the montane plantation in Arizona (8,000 feet), at the Desert Laboratory (2,300 feet), and at the Coastal Laboratory at Carmel, California, have now been carried so far that a number of species are growing under the widely different climatic complexes offered by these localities and are offering some marked somatic accommodations, some of which, as previously noted, are not in the nature of adaptation or fitting adjustments. Analytic studies of these species have been begun. The general character of the available results is denoted by the data obtained from one of these forms given below.

Structural Alterations Induced in a Mountain Strawberry (Fragaria ovalis) in Desert and Coastal Habitats, by E. M. Kupfer.

Fragaria ovalis, from 7,000 to 8,000 feet in the Santa Catalina Mountains of central Arizona, has been propagated at the Desert Laboratory and at the Coastal Laboratory at Carmel, California, for three years. Considerable variation from the typical habit has been recognized, and some of these features have been noted in previous reports. Dr. Kupfer has begun a detailed study of the structure and composition of plants grown under the entire range of conditions and has detected some striking alterations in stomatal characters and in chemical composition of membranes.

Pollination through Decapitated Pistils, by E. M. Kupfer.

Dr. Kupfer continued some work designed to ascertain the office of the stigma in pollination of seed-plants at the Coastal Laboratory during July and August 1912, and some possible results in fertilization through decapitated stigmas were obtained.

Alterations Induced by Ovarial Treatments of Plants, by D. T. MacDougal.

A general résumé of the results obtained in the cultivation of a series of generations of forms derived by ovarial treatment of plants was published in 1911. The continuation of this work involves continued attention to a number of slowly maturing species and no new treatments have been made within the year, as facilities for cultivation have not yet permitted the sowing of all the seeds from treated ovaries obtained early in 1911.

Evolution of the Chrysomelid Beetles, by W. L. Tower.

The Livingston atmometer having been found to be a very delicate and reliable indicator of the integration of environmental factors, some attention has been devoted to perfecting a form of this instrument with a globular cup which would give more perfect exposures. Methods of standardization have also been improved.

The set of cultures as reported in last year's statement has been continued, is progressing unusually well, and gives promise of further valuable data. Of especial interest is the continued manifestation of the mutation phenomena shown in some of the cultures, showing that a mutating stem-stock can be produced as a result of hybrid synthesis and that this remains stable or can be broken up in a mutating fashion, depending upon the environmental complex in which it is placed, or upon unusual incident factors. These results at Tucson have contributed largely to the formation of a new hypothesis of mutation, published in outline during the present year (chapter VII, Heredity and Eugenics, University of Chicago Press, 1912). It is believed that this method of producing mutating strains is of fundamental theoretical significance and may be of much practical importance.

The transplanted culture of *Leptinotarsa decemlineata* at Tucson has changed in eight generations, so that in the winter time it is unable to meet the conditions of the ancestral environment at Chicago when returned to that city and placed side by side with the original stock. The reason for this is the change in the character of the Tucson population, slowly and progressively, as to the capacity for retaining water in their tissues through the hibernating period, and of giving it up slowly, so that the desiccation of the dry season shall not be fatal. When taken to Chicago and allowed to hibernate in the late summer, which they do naturally, they are absolutely unable to pass the winter alive, owing to the fact that they can not eliminate water fast enough, as the temperature drops, to keep the freezing-point of the tissues below that of the medium. As a result they are killed by the cold of the winter. Like results are now available in some other species from the south which are not able to survive our northern winter for this reason, and this relation persists as a germinal factor in the race. Relations of this nature have played important rôles in the distribution and evolution of organisms in nature.

Of interest in this report are the results obtained in a series of experiments originally carried on in duplicate at Chicago and in the desert regions of Tehuacan, Mexico. This latter part was in 1908 transferred to Tucson as the natural desert complex, but met with repeated disaster. The Chicago portion of the experiment, in which an artificial desert complex was brought to bear upon the pure *L. signaticollis* stock at early stages in the development of the ova, has resulted in the production in the surviving portion of the experiment of permanent changes in the antennæ of a character and degree that if found in nature would be given generic value in taxonomy and one of them of subordinal value, as these things are rated by taxonomic workers. We hope to overcome the technical difficulties at Tucson and there duplicate in nature the results obtained in the laboratory at Chicago. These changes are dominant over the normal form and might well serve as the basis of creating new generic groups by experimental methods.

The general oversight of the work at Tucson has during the year been in the care of Mr. J. K. Breitenbecker, and much of the satisfactory progress and the present fine condition of the cultures and the plants at Tucson is due to his industry and intelligent aid.

The Water-content and Activity of Animal Organisms, by J. K. Breitenbecker.

Observations upon the relation of water-content and the functional and habitual activity of organisms under arid conditions have been carried on during the summers of 1911 and 1912. Chief attention has been paid to insects, and most of the data have been obtained by a study of the extensive series of Leptinotarsæ organized by Prof. W. L. Tower, which have been under

Mr. Breitenbecker's care. The proportion of water in the bodies of insects depends very largely upon the moisture-content of the medium in which they are found. The proportion of water held in the body, or the water-balance, is correlated with various activities, and the lowering of this balance, or surplus, inhibits several functions or processes, and is also followed by reversed response to various external agencies which may exert a stimulatory action. Reproduction ensues during the stage of highest water-content.

Many of these forms show great localization in their distribution in the desert, and the ruling feature of the environmental complex, whether it entails a habitat in trees, among rocks, or in the soil, is that of moisture-content, which determines the behavior of the animals present.

The animal organisms of the desert show but few external characteristic xerophilous characters, but they display a very remarkable degree of coincidence of the cycle of activity and reproduction with the rainy season and their cycle of dormancy with the drier season, *regardless of any apparent structural adaptations.*

The Climatic Factor, by Ellsworth Huntington.

During the past year the investigations of Prof. Ellsworth Huntington have been prosecuted along three lines: (1) a study of possible changes of climate in regions not hitherto investigated in this regard; (2) a further attempt at a mathematical measurement of any changes which may have occurred; (3) an inquiry into the possible relation of such changes to other types of phenomena, both physical and human.

In pursuance of the first line of research, a journey was made to Mexico and Yucatan during March and April. It was there found that even in the far south, well within the torrid zone, the alluvial terraces of mountain valleys and the strands of old lakes present evidences of climatic changes as marked as those of other arid parts of the world, whether in America or the eastern hemisphere. Moreover, traces of ancient cultures buried beneath alluvium, on the one hand, and the historic accounts of the Spanish Conquest and of the times immediately preceding it, on the other hand, indicate distinctly changeable conditions of water-supply. In moister portions of the tropics, such as central Yucatan, ruins in the midst of dense tropical forests appear to indicate that when Arizona and regions in similar latitudes were moister than now, those which lie farther south on the border of the zone of equatorial rains were drier than at present. Thus it appears that while climatic pulsations may be accompanied or occasioned by changes in the general temperature of the world as a whole, and by a general increase or decrease of precipitation, they are more strongly characterized by variations in the activity of the aërial circulation; that is, certain epochs are apparently marked by strong winds and hence an equatorward shifting of the more northerly climatic zones in winter, while other epochs are marked by weak winds, slight movements of the climatic zones, and relative uniformity of the seasons.

The second object of the year's study—the mathematical measurement of changes of climate—has been accomplished by means of further investigation of the rate of growth of old trees. Several thousand stump analyses gathered from various parts of the United States by the U. S. Forest Service were most courteously placed at the disposal of the Carnegie Institution of Washington by the Forester, Mr. H. S. Graves. From these a series of 16 corrected curves of growth have been prepared. They show the growth of the trees during a period of from 300 to 1,000 years and prove that it has varied greatly from time to time. The variation is cyclic in character, and is of such a nature that it can not be due to fires or other accidents, and must apparently be of climatic origin. The full interpretation has not yet been made, since different trees are stimulated by different conditions, some responding to warmth, others to abundant moisture, and still others to other conditions, according to the habits and habitat of the species. Hence, before the climatic conditions of any given part of the country during past centuries can be ascertained exactly, it is necessary to determine the precise conditions which stimulate or repress the growth of the various species. This can be done by comparing a series of annual measurements for the last 50 years, more or less, with the nearest available meteorological records. This comparison has been made in the case of the yellow pine by Prof. A. E. Douglass at the request of Mr. Huntington, and in the case of the *Sequoia gigantea* by Mr. Huntington himself. In 15 other cases, however, it must be deferred until a series of measurements of annual growth can be secured, the measurements furnished by the Forest Service having been made by decades.

The most important work of the year was a further study of the Big Trees of California. In addition to the 250 measurements of stumps made last year, about 650 more were made, a total of nearly 900 measurements upon 450 trees. The total number of individual readings is in the neighborhood of 130,000, while the number of rings actually counted now amounts to about 1,300,000. The work of tabulating this mass of figures is well under way, and will be completed before the end of the calendar year. It will enable us to draw a curve showing in detail how the climate of California has varied for the past 3,000 years; and this curve will possess a degree of accuracy far greater than has hitherto been supposed possible. It will furnish a mathematical key to the past climate not only in America, but of the eastern hemisphere; and it will probably be one of the important steps toward the prediction of climatic changes which may occur in the future.

To facilitate the obtaining of measurements of tree growth in remote regions, a boring machine was constructed and was given a thorough trial in California. It worked well, save that a further device for clearing shavings is necessary. When this is added the machine will be a valuable aid in procuring sections of wood in the form of horizontal cores from trees in places where no freshly cut stumps are available.

The pursuit of the third object of the year's work, the inquiry into the possible relation of climatic changes to other types of phenomena, was at-

tempted primarily in the hope of obtaining some light on the cause of such changes. The synchronism of two apparently independent sets of phenomena suggests a possible relationship; the two may be related as cause and effect, or they may be due to some common outside cause. When Mr. H. W. Pearson, of Duluth, pointed out an apparent synchronism between his supposed changes in the level of the sea and the changes in climate inferred by Mr. Huntington, it appeared advisable to investigate the matter. Mr. Pearson kindly put his notes at the disposal of the Institution. An examination of them brought out the interesting fact that most of the supposed evidences of changes in sea-level was in reality evidence of changes in the land. Rapid filling of river mouths took place at the supposed times of a falling of sea-level, which were times of aridity according to the inferred climatic changes; while the flooding of swamps and the cutting of embankments took place in the times of supposed rising of sea-level, which were also times of moisture. The rapid deposition of silt by rivers is characteristic of arid periods, while severe storms are characteristic of wet periods. Hence the supposed synchronism of changes of sea-level and changes of climate does not seem to exist, but in its stead we have a new type of evidence of changes of climate.

Another similar line of research has yielded results of much more importance. Meteorologists have concluded that the climate of the earth is characterized by an eleven-year cycle which has a relation of some sort to the sunspot cycle of similar length. Several authors have concluded that earthquakes and volcanoes also occur in eleven-year cycles synchronizing with that of the sun. If climatic and seismic cycles synchronize with those of sunspots, it is probable that they synchronize with one another. To test this a list of all known earthquakes since the beginning of the Christian era was prepared by Miss Ethel B. Kirkton. From this a curve of seismic activity has been plotted for comparison with the curves of climate derived from the Big Trees and other sources. The degree of agreement is such as to afford ground for most interesting speculations as to the possible relation of climatic changes, earthquakes, and volcanoes to one another and to the sun.

Inasmuch as the investigation of changes of sea-level yielded only a negative result, the funds intended for it were turned toward the preliminary steps of another line of research. This was a mathematical study of the effect of diverse conditions of climate and weather upon human efficiency and activity. Statistics were gathered as to the rate of piece-work in factories day by day under varying conditions of weather. The long process of tabulating and computing these has only been begun. Nevertheless indications have already been found that changes of weather produce effects hitherto unsuspected. For example, it appears that absolute temperatures are less important than variations of temperature. Change of almost any kind seems to be stimulatory. Further investigations in various parts of the country are needed in order to test the matter. Many other relationships

will probably appear, and it will ultimately be possible to construct a map showing just what effect the climate of different parts of the country has upon the average efficiency of different races.

The climatic researches of the years 1910, 1911, and 1912 have now reached a point where the evidence as to changes during the past 3,000 years needs to be summed up and placed in permanent form. Accordingly a volume entitled "The Climatic Factor" has been written and will be ready for the press as soon as the final tabulation and computation of the statistics of the Big Trees is completed. It deals almost exclusively with the problem of the reality, date, and nature of climatic changes, and their relation to phenomena such as earthquakes. The problems of the relation of such changes to man and of the prediction and effect of future changes must be left for another volume.

EQUIPMENT.

The experimental tract at Carmel has been enlarged by the purchase of an additional series of lots, and the total area now in possession of the Department at this place appears to be adequate to the needs of the work to be carried out in connection with the Coastal Laboratory. Additions have been made to the furniture and fittings placed at the disposal of the various workers. The mechanical equipment has been kept to its efficiency by the usual repairs and purchases.

The laboratory equipment has been increased by the acquisition of a Palmer vacuum-pump run by an electric motor and by several small pumps and clinostats designed and constructed by Mr. Stanley Sykes. A recording rain-gage built to meet the requirements of Dr. Shreve's work on evaporation and soil-moisture has been constructed by Casella & Co., of London. Electric ovens and other minor instruments have been bought as needed.

COOPERATION, FIELD WORK, AND TRAVEL.

Twenty-two members of the staff, Research Associates, and other persons collaborated under the auspices or by the aid of the Department during the year.

Professor Peirce's investigations of organisms in condensing brines were carried out in the laboratories of Stanford University; Professor Brannon's analysis of the action of Salton water on woods at the University of Chicago; Dr. Vinson's analysis of Salton Lake water in the laboratories of the agricultural experiment station of the University of Arizona; Professor Richards's work on the respiration of cacti in the laboratories of Barnard College, Columbia University, and at the Desert Laboratory; Professor Huntington's climatological work has taken him into the field in southern Mexico, into the groves of giant trees in California, to the Coastal Laboratory at Carmel, and to his own department in Yale University; Professor Lloyd's stomatal and transpiration studies have been carried out at the Coastal Laboratory, the Desert Laboratory, and the Alabama Polytechnic

Institute; Professor Johnson's morphological and physiological studies of the fruits of the cacti have taken him to the Desert Laboratory, the Marine Laboratory at South Harpswell, Maine, and also to his own laboratory in Johns Hopkins University; Professor Livingston's researches on soil-moisture have been at the Desert Laboratory and in the laboratories for plant physiology of Johns Hopkins University. The study of the Cactaceæ by Drs. Britton and Rose has been carried out in quarters furnished by the Smithsonian Institution, and the facilities of the New York Botanical Garden have been placed at the disposal of the Research Associates in charge of this investigation. Dr. Rose has also visited the principal botanical centers of Europe, in which material has been collected, and perfected arrangements for the comprehensive study of this group of desert plants.

Dr. Shreve has carried out observations in connection with his geographical studies at the montane plantations in northern Arizona, Utah, Nevada, and California, and Mr. G. Sykes has worked in the map collections of the British Museum, the library of the Royal Geographical Society, and the Bancroft collection in the University of California, and accompanied the Director as stated below. Dr. H. A. Spoehr has used the facilities of the chemical department of the University of Chicago and consulted the John Crerar Library of Chicago. Dr. D. T. MacDougal has spent some time at each of the laboratories of the Department; carried out field work in the Cahuila Basin around and on the Salton Lake, carried a line of observations across the Mohave Desert and the Tulare Valley, and early in the year, in company with Mr. G. Sykes, made a traverse of the Red Sea province of Sudan, which was extended south to Khartum, and later a caravan trip of 600 miles through the Libyan Desert. Other work not especially mentioned has been prosecuted at the laboratories of the Department. Visits were made to nearly all places in which cooperative work was carried on, and numerous lectures were given by the Director and members of the staff at various places from Stanford University to London and Hamburg.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

The work of this Department has now reached the point at which its progress depends mainly upon the amount of time which the collaborators are able to devote to finishing, with the materials and means at their command, their respective contributions to the economic history of the United States. Though no one of them is able to give his entire time to the work, several have taken partial leaves of absence during the past year and are planning their regular work for the coming year so as to have more time for the work of the Carnegie Institution of Washington. The additional appropriation of $12,500, which was granted last year at our request, will enable us to push the completion of the work in hand more rapidly, and there are at least three of the divisions whose subjects are so well advanced that we can hope for a conclusion of their work within a comparatively short time.

In view of this fact, the writer respectfully calls the attention of the Trustees to the desirability of making plans for a permanent organization of this Department. As pointed out in last year's report (see page 70, Year Book for 1911) the Contributions to American Economic History are in the nature of preliminary work. The present organization, which is well adapted to this particular task, would not be effective in a permanent department, which should be able to command the services of a regular force of salaried experts. While the collaborators would be exceeding their functions, if they were to suggest plans for such a future organization, the Chairman feels confident that they would be glad to respond to any request that the Trustees might make with regard to the matter, and, either as a body or in collaboration with other economists, block out the framework for a permanent organization. The establishment of a permanent Department of Economics and Sociology, coordinate with the other departments of the Carnegie Institution of Washington, need not be delayed until the completion of the present undertaking, which could well be carried forward independently of, though in harmony with, the new department.

Details of the work of the past year as reported by the heads of the several divisions are given below.

DIVISION I.—POPULATION AND IMMIGRATION.

Prof. Walter F. Willcox has arranged to have his work at Cornell University reduced to half its usual amount during the coming year, in order that he may devote more time to the work of his division. The time which

* Address, Yale University, New Haven, Connecticut. (For previous reports see Year Books Nos. 3–10.)

he had hoped to spend upon it during the summer has been unexpectedly curtailed by the demands of the International Congress of Hygiene and Demography, but this cause of delay will soon be a thing of the past.

Division II.—AGRICULTURE AND FORESTRY.

Of the various parts of the report of this division, which are being prepared under the direction of President Kenyon L. Butterfield, the introductory chapter on Economic Characteristics of the Agricultural Industry, by Prof. Thomas N. Carver, of Harvard University, was completed some time ago. The chapter on American Agriculture down to 1840 is in the hands of Prof. F. W. Blackmar, of the University of Kansas, who has done considerable preliminary work, but has been so delayed by the pressure of academic duties that he has been desirous of giving up the work. He has, however, consented to continue and hopes to be able to have the greater part of his material in shape by the end of next year.

Prof. Henry C. Taylor, of the University of Wisconsin, who is preparing the chapter on the history of agriculture since 1840, reports that the Industrial History of the Valley of the Red River of the North (pp. 146), by John Lee Coulter, has been published by the State Historical Society of North Dakota; and a monograph on the reorganization of agriculture in Georgia, 1865 to 1910, by R. B. Brooks, of the University of Georgia, has been handed in.

The main part of the work on the history of agriculture since 1840 is being conducted in Professor Taylor's research laboratory. Mr. O. E. Baker devoted practically all of his energy to this work during the past year and Mr. J. I. Falconer has been employed for the coming year. Professor Taylor has tried to supplement the appropriation of the Carnegie Institution of Washington by income received for partially completed data, for articles, and for the privilege of printing maps. He is assisted at the present time by Mr. L. C. Gray and Mr. J. I. Falconer, both of the University of Wisconsin.

Prof. Benjamin H. Hibbard, of Ames, Iowa, who is writing the chapter on the public land policy, has been steadily at work upon his topic and expects to have the manuscript ready by Christmas time.

Prof. Edward D. Jones is at work on the American Domestic Market since 1840, and has been publishing a series of articles "to serve as a trial of the material." These preliminary studies have appeared in the trade journal entitled "Mill Supplies," and the dates and subjects are as follows:

Standardization in Modern Commerce, February 1911.
Buyers' Specifications, April 1911.
Quantity Prices, May 1911.
The Cancellation of Orders, June 1911.
Price of Resale and its Control, July 1911.
The Relation of Brands and Advertising, August 1911.
Our System of Weights and Measures, September 1911.
Our System of Commercial Grading, October 1911.
Modern Problems of Price, Dec. 1911.
Price Changes, January 1912.
The Ideal of a Perfect Market, Feb. 1912.
The Marketing of Agricultural Products, April 1912.
The Cost of Living and Retail Trade, July 1912.
The Principles of Modern Retail Merchandising, August 1912.
The Functions of the Merchant, September 1912.

Division III.—MINING.

No monographs have been published since the last report was made nor have any completed manuscripts been received. Mr. E. W. Parker reports, however, that good progress is being made in the following subjects:

The *iron-ore industry:* Prof. C. K. Leith and his assistant, Mr. R. J. Holden. A large part of the manuscript has already been written.

The *copper-mining industry:* Mr. L. C. Graton has been fortunate enough to secure from Dr. James Douglas, one of the highest authorities on the history of mining and metallurgical copper in the world, his unpublished manuscript on the history of the copper industry. He has also secured the services of Mr. Joseph Murdoch, of Allston, Massachusetts, and it is probable that certain chapters will appear under the joint authorship of Dr. Douglas and Mr. Graton.

The *quarrying industry:* Dr. F. B. Laney's work with the U. S. Geological Survey has prevented him from giving as much time as expected to the completion of his report, but he has made considerable progress with the assistance of Mrs. Laney.

Mining law: Mr. William E. Colby has almost finished this section, and is now giving it the finishing touches.

It is expected that all of the above subjects will be completed by the first of the new year, and Mr. Parker expects a leave of absence from the U. S. Geological Survey in order to enable him to complete the work of the division.

Division IV.—MANUFACTURES.

Dr. Victor S. Clark is still prevented by official duties from devoting more than a small share of his time to the work of this division, having been called from Honolulu to do some work for the government in Japan and Manchuria and then in Europe. His report, dated August 30, 1912, was written in St. Petersburg. No monographs have been completed or published during the past year, but Dr. Clark has made some progress in assembling his notes.

Division V.—TRANSPORTATION.

Dr. B. H. Meyer is obliged to devote most of his time to the work of the Interstate Commerce Commission in Washington. Miss MacGill has, however, been making good progress during the past year in work upon his first volume, and Dr. Meyer has recently engaged Dr. Herman A. Brauer to assist her. There is, therefore, a fair prospect that one volume will be completed very soon.

Division VI.—DOMESTIC AND FOREIGN COMMERCE.

Since the last report a monograph, "A History of New England Fisheries," pp. 457, by Raymond McFarland, has been published. This is included among the publications of the University of Pennsylvania.

Professor Johnson expects to take a leave of absence from the University of Pennsylvania from February 1, 1913, to September 1913, and to give his time to the work of the division. He reports as follows regarding unfinished work:

The history of the coastwise trade of the United States, which was undertaken some years ago by Asst. Prof. Thomas Conway, jr., is now practically completed. A part of it has been copied, and the author promises to have the entire work completed within a short time.

There is no unfinished work due from collaborators.

I am being assisted in the work by Mr. T. W. Van Meter, assistant in transportation and commerce, University of Pennsylvania. Mr. Van Meter is assisting me in the preparation of the final volume, the earlier portions of which I have already written. Beginning with 1913, I expect to have the assistance of Dr. G. G. Huebner, assistant professor of transportation and commerce, University of Pennsylvania. With the aid of these assistants it is my hope to have the work completed by the autumn of 1913.

Division VII.—MONEY AND BANKING.

Prof. Davis R. Dewey reported in July as follows:

I am now devoting myself exclusively to the preparation of manuscript, and, if I can continue during the remainder of the summer without serious interruption, I hope to have a considerable block of the work accomplished in the fall. The enterprise has now reached a stage where all depends upon my own personal efforts rather than upon that of the collaborators.

Division VIII.—LABOR MOVEMENT.

Prof. John R. Commons reports that the following monographs have been completed since the last report:

History of the labor movement during the forties and fifties. By Henry Hoagland.
Movement for shorter hours 1825-1880. By Lorian P. Jefferson.

The following monographs are nearly completed:

History of the labor movement from 1825 to 1837. By Dr. Helen L. Sumner.
History of socialism and anarchism in the United States. By Selig Perlman.
The Knights of Labor. By David J. Saposs.
The American Federation of Labor. By Edwin E. Witte.

In regard to the completion of the work, Professor Commons states that he expects to finish the final volume in the spring of 1913.

Division IX.—INDUSTRIAL ORGANIZATION.

As stated in previous reports, Prof. J. W. Jenks has done considerable preliminary work, but, in order to avoid duplication, is suspending further activity until the reports of some of the other divisions are finished.

Division X.—SOCIAL LEGISLATION.

No monographs have been handed in since the last annual report, and none published, though negotiations are pending for the printing of several of those already accepted. The following studies are still unfinished:

Anti-trust legislation of Wisconsin, Minnesota, Iowa, and Nebraska. By C. L. Waldron.
The labor legislation of Maryland. By H. Wirt Steele.
The labor and rural credit policy of the Southern States. By D. L. Peacock.

Mr. Nathan Isaacs has undertaken, at his own expense, to revise and bring down to date his study of the mining laws of Ohio, Indiana, and Illinois.

The writer spent a good part of his time during the past winter in working over the material already gathered, which he used in university lectures, and has devoted most of the summer to the subject. He is planning his academic work for the coming year with special reference to his work for the Carnegie Institution of Washington, and as he has succeeded in finishing some other tasks of long standing, he hopes to make substantial progress on the study of social legislation during the coming winter.

Division XI.—FEDERAL AND STATE FINANCE, INCLUDING TAXATION.

Prof. H. B. Gardner obtained a release from his academic duties during the past year and devoted himself to the study of the Federal finances. The work proved difficult, but he covered the first 25 years. He has been unfortunately prevented by sickness in his family from giving much attention to the work of the Carnegie Institution of Washington during the summer, but expects to continue upon it during the coming winter. It is probable that the results of last year's work will be published by the American Statistical Association.

The following publications have been made during the past year:

Financial history of Ohio. By Prof. E. L. Bogart, University of Illinois. Vol. I, Nos. 1 and 2, in University of Illinois Studies in the Social Sciences. (Parts of this monograph have been published in periodicals as follows: Recent tax reforms in Ohio, The American Economic Review, pp. 505–518, September 1911.
Taxation of the second Bank of the United States by Ohio, American Historical Review, vol. XVII, No. 2, pp. 312–331. January 1912.)
Financial history of Connecticut, 1789–1861. By Dr. Henry C. Walradt. Transactions of the Connecticut Academy of Arts and Science, vol. 17, pp. 1–139, March 1912.

The following monographs have been completed but not published:

Financial history of California. By Mr. W. C. Fankhauser. To be published by the University of California. (Mr. Fankhauser continued and completed the work originally undertaken by Prof. C. C. Plehn, of the University of California.)
Financial history of Vermont. By Dr. Frederick A. Wood.

Professor Gardner furnishes the following list of studies, upon which substantial progress has been made and which should be completed during the coming year:

Financial history of New York. By Mr. Don C. Sowers. To be published by Columbia University.
Financial history of Illinois. By Mr. Robert M. Haig. To be published by Columbia University.
Financial history of Pennsylvania. By Dr. Clyde S. King, of the University of Pennsylvania.
Financial history of North Carolina. By Prof. W. K. Boyd, of Trinity College, Durham, N. C.
Financial history of Texas. By Prof. E. T. Miller, of the University of Texas. Published in part; see Report for 1911.

Studies upon which a substantial amount of work has been done but concerning which there is no definite report of progress during the year:

Financial history of Connecticut since 1861. By Dr. Henry C. Walradt.
Financial history of Tennessee. By Prof. St. George L. Sioussat, Vanderbilt University.
Financial history of Virginia. By Mr. Edgar Sydenstricker. Practically complete.
Financial history of Michigan. By Prof. Wilbur O. Hedrick, Michigan Agricultural College.
Financial history of Minnesota. By Prof. R. V. Phelan, University of Minnesota.
Financial history of South Carolina. By Mr. George McCutcheon, University of South Carolina.
Financial history of New Jersey. By Prof. Edgar Dawson. Professor Dawson has been compelled to abandon the completion of this study.
Comparative study of the financial development of certain of the larger cities of the United States. By Prof. Oliver C. Lockhart, Ohio State University.
License taxes in the Southern States. By Prof. H. A. Millis, University of Kansas.

Division XII.—THE NEGRO IN SLAVERY AND FREEDOM.

Mr. Alfred Holt Stone is still unable to leave his plantation and his work is, therefore, necessarily delayed. It is, however, by no means abandoned, and as soon as his business interests permit, Mr. Stone expects to resume work on the subject, on which he had already made considerable progress when the boll-weevil forced him to go to the defense of his property.

The following study has been published:

Negroes who owned slaves. By Calvin Dill Wilson, Popular Science Monthly, pp. 483–494, November 1912.

INDEX OF STATE DOCUMENTS.

Since last year's report Miss Hasse has completed the Index of State Documents of Ohio, and it has been issued by the Carnegie Institution of Washington in two volumes, containing in the aggregate 1,136 pages. This is the most voluminous of any of the State indices thus far issued, and reflects great credit upon the industry and skill of Miss Hasse. She is at present working on the States of Pennsylvania and New Jersey.

The following is a complete list of States published, with the year of publication:

California	1908	New Hampshire	1907
Delaware	1910	New York	1907
Illinois	1909	Ohio	1912
Kentucky	1910	Rhode Island	1908
Maine	1907	Vermont	1907
Massachusetts	1908		

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. DAVENPORT, DIRECTOR.

The present year has marked an advance in that cytological, chemical, and morphological studies on mutation and pigmentation have moved far along converging lines. From several points of view new light has been gained on the nature and control of sex. The studies on human heredity have made substantial progress.

DETAILED REPORTS ON SCIENTIFIC WORK.

ORIGIN AND CYTOLOGICAL BASIS OF MUTATIONS.

One of the most striking results of the year is a demonstration, more complete than has been made hitherto, of the conclusion that has long been held in a semi-speculative way, that the chromosomes of the cell contain materials that determine the direction of development of the organism and the details of its structure. The demonstration has been made in this wise: Usually a given species has a definite and constant number of chromosomes in all individuals that are capable of reproduction. But in *Oenothera lamarckiana* and its mutants the number is variable. This fact was early demonstrated in our cultures of the evening primrose by Miss Anne M. Lutz. Thus she found 14 chromosomes in the tissue-cells of the form *lamarckiana*, 15 chromosomes in the form *lata*, and 28 chromosomes in the form *gigas*. Thus, each of these characteristic forms of the primrose, separated by marked differences of form and size, has its special condition of chromosomes. The conclusion can hardly be escaped that each special condition of the chromosomes determines the peculiarities of the form of the adult body; and, in general, within cultural limits, what the organism shall develop into is determined by its germ-plasm.

Miss Lutz's studies throw light specifically on the mutability of the evening primrose. They indicate that the primrose is mutable just because in it the mechanism for exact division of the determiners, at the ripening of the germ-cells, is imperfect and irregular. The reason for this irregularity is, in part, an inequality in the number of chromosomes that have come from the two parents, so that there are one or more unpaired chromosomes whose fate in the maturation of the sex-cells is undetermined and variable and, consequently, results in variable combinations of determiners, and so in variable progeny. The suggestion arises that "mutation" is always induced by some irregularity in chromosomal division—a condition that may, prob-

* Situated at Cold Spring Harbor, Long Island, New York. Grant No. 742. $37,477 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 3-10.)

ably, be initiated by the hybridization of the two forms with an unequal number of chromosomes.

PIGMENTATION.

Of all the morphological characters of organisms the pigment is one of the simplest and its manufacture would, it is to be expected, lend itself most readily to modification by chemical and other means. Thus it is known that sunlight influences (even in the human skin) the formation of pigments, and that animals removed from the influence of sunlight, such as those that live in caves, in grottoes, or within opaque shells, develop little or no pigment. It has often been gratuitously assumed that they had lost the power of manufacturing materials for pigment, but experiment shows that this is not always so, for, subjected to sunlight, pigment appears. It was hoped that in our artificial cave pigment-production would be inhibited in some animals as in the caves, and this proves to be the case. The salamander (*Amblystoma*) larvæ that have hatched in the cave and are now a year and a half old are still "white"—they have no more pigment than many cave species of long standing. Nevertheless, pigment production is not wholly inhibited. The mud minnows (*Umbra limi*) which have been kept in the cave for nearly 2 years are showing a progressive reduction in amount of pigment. Other material in the artificial cave gives promise of especially interesting results. These studies have been made by Dr. Banta.

In our studies on the inheritance of plumage color in poultry it early developed that there are two kinds of whites, namely, whites which when mated with pigmented birds give pigmented offspring, and whites which when mated with pigmented birds give only unpigmented offspring. Indeed, these two kinds of whites, recessive and dominant, are now recognized as widespread in nature. The white of sheep's wool is another dominant discovered by us. According to modern methods of interpretation, recessive whites are those whose lack of pigment is due to an absence of one or more of the factors necessary to pigment production. And dominant whites are to be explained on the assumption of some additional factor. What that additional factor might be has been unknown, and Dr. Gortner has been seeking for it. Now black pigment, "melanin," is produced by the oxidation of tyrosin in the presence of an oxidizing ferment, tyrosinase. It was suggested by Spiegler, before Dr. Gortner began his work, that the dominant white was due to a superoxidation of the melanin. If this conclusion were correct it should be possible to isolate the melanin—only it should be *white*. Dr. Gortner soon showed that Spiegler's conclusion was wrong. The "white melanin" from sheep's wool is only the insoluble portion of the keratin and is not pigment at all. It seemed probable, consequently, that the dominant factor in white wool is an *inhibiting factor,* which prevents the pigment-forming elements, though present, from combining. This explanation remained pure hypothesis until tested, and this test Dr. Gortner, working with

Dr. Banta, has made, with results that support the hypothesis. The experiments are as follows: To the water in which the eggs and larvæ of *Spelerpes bilineatus* (which are typically dark brown) are developing have been added certain phenols—substances that are known to inhibit the oxidation induced by tyrosinase. The result has been an almost complete inhibition of pigment formation. The larvæ, instead of being dark brown, are cream colored. The obvious conclusion is: tyrosin only in the body gives recessive *white;* tyrosin + tyrosinase give melanic pigment, that is, *dark brown;* tyrosin + tyrosinase + a phenol give dominant *white.* Further details are given in the following report of Dr. Gortner:

It was found, if phenols carrying the hydroxyl groups in the *ortho* or *para* position are treated with tyrosinase, that oxidation to a color results. If, however, to this mixture a small quantity of a phenol carrying the hydroxyl in the *meta* position be added—for example, a small quantity of phloroglucinol, orcinol, or resorcinal—not only does no oxidation of the *meta* compound occur, but the addition of the *meta* dihydroxyl phenol inhibits the action of the tyrosinase on those phenols which are easily oxidized to colors. A study of this reaction showed that the *meta* dihydroxyl compound neither united with the added tyrosin nor was it oxidized itself, but that the reaction in the test-tube was exactly analogous to that of an anti-oxidase, only in this instance the reaction was purely chemical, and not due to an enzyme. The suggestion was made that perhaps it is due to a reaction of this sort that the cause of dominance is due, *i. e.,* that the chromogen is changed by some reaction from a *para* phenol to a *meta* phenol; *e. g.,* tyrosin is changed from *para* hydroxyphenyl α-aminopropionic acid to meta hydroxyphenyl α-aminopropionic acid, thus preventing the black pigment from developing and producing a dominant white condition. It is of especial interest to note that Keeble and Armstrong (Proc. Roy. Soc. B., 85, p. 214), acting on the hypothesis that an anti-enzyme causes the dominant white condition, have recently proven that this hypothesis is correct for material from the Chinese primrose.

THE ORIGIN AND HEREDITY OF SEX.

It was early seen that the new methods of studying heredity would throw light on the question of the determination of sex; and indeed great progress has been made in this and other countries by the combination of the investigations of cytologists and breeders. It is now generally recognized that a certain chromosome usually distinguishable from its fellows and which is, essentially, unpaired and so is carried by only half of the progeny of any pair of parents, determines that its bearer shall be of a given sex. The other half are of the opposite sex. This sex-determiner carries with it other characters than merely those that are combined with sex; and these are the sex-limited or sex-linked characters. The hunt for sex-limited characters has yielded many surprises. In the last few years the Director has studied a case of a sex-limited character in poultry and found that the color of the margin or "lacing" of the neck, or "hackle" feathers, is sex-limited; and that, when crosses are made between races with red and those with white

hackle, the daughters show the color that their father has. The reason is that this is a character linked with the sex chromosomes and the daughters get their sex chromosome from their father only, while the sons get a sex chromosome from each side of the house. Occasion was taken, in printing these results, to review cases of sex-limited inheritance in birds and to bring all results into accordance with a simplified formula. Dr. Shull has discovered a sex-limited character in his *Lychnis* cultures—the first case to be observed in plants. Here a narrow-leafed condition is in the offspring of hybrids found only in male plants.

Plants are usually unsatisfactory for the study of sex-limited characters because they are so often hermaphroditic. In some species, however, as noticeably in the cockle, *Lychnis,* males, females, and hermaphrodites occur side by side in the same culture field. The females are usually sharply differentiated from the others, but the males are only extreme cases of abortion of female organs in an hermaphrodite. Many sperm, indeed, carry the determiner for hermaphroditism, the others that for femaleness; but the eggs ordinarily carry only the determiner for maleness. It now appears, however, that some eggs do carry the determiner for hermaphroditism; and it was hoped to get a union of eggs and sperm which should be positively homozygous in respect to the determiner for hermaphroditism, that is, should have it double-derived from both parental germ-plasms. Such a product should be the ancestor of a pure hermaphrodite strain. But, so far, Dr. Shull has met with disappointment. Always there arise eggs that do not carry the determiner for hermaphroditism, but femaleness only.

Usually, we expect that half of the offspring in all forms shall be females; but we know exceptional cases where, as in plant lice and rotifers, female children only are born for many generations. In *Lychnis,* also, expectation is not fulfilled; for the sex-ratio of the female sex varies all the way from 4 per cent to 97 per cent in different families of large size; and making all counts, it appears that the females constitute about 62 per cent instead of the expected 50 per cent.

A third study of sex was made by the Director in collaboration with Professor Arkell, until recently in charge of the New Hampshire experiment station at Durham, with which this station has been cooperating. This study had to do with the horns of sheep. As is well known, in some races (Merinos) the males are usually horned, the females hornless, and this fact has been explained on the ground that the testis secretes a substance (which the ovary lacks) that stimulates the formation of horns. A difficulty lies in the fact that in other races of sheep, as in most sorts, both ewes and rams are horned, and in other races neither sex. So the data gathered from the sheep-breeding experiments of both stations were gone over and it appeared that the facts were not opposed to the conclusion that the horns of sheep likewise are inherited as sex-limited characters. A note was published in Science to that effect, and in consequence of a criticism of this conclusion

urged by our colleague, Dr. Castle, the germ-gland has been removed from a horned ewe lamb and from a horned ram lamb. It is also planned to make studies on castrated rams on farms near by. The experiments seem worth while in order to bring under a general rule the outlying case of horns in sheep.

SEX STUDIES IN POULTRY.

A fourth series on this subject treats of the interrelation of sex-glands and somatic coloration. Poultry, like birds in general, are markedly dimorphic in coloration. Mr. Goodale removed the left ovary (which alone normally functions) from a duck that was 12 weeks old. This bird continued to develop female plumage for more than a year, but finally acquired so much of the plumage of the male as to be easily mistaken for such. Autopsy revealed the fact that the removal of the ovary was complete and the right gland was also lacking. The only oviduct was the normal left one and that was in a juvenile condition. Thus this bird that had gained the male plumage was an unsexed female. Another case of even greater interest, also worked out by Mr. Goodale, is that of a Brown Leghorn female from which the left ovary was removed when the bird was less than a month old and which assumed most, but not all, of the characters of the male. When the bird was about a year old an autopsy was made and, in place of the removed ovary and on the right side also, there was found a small organ, sections of which showed a mass of cells that were undifferentiated and very different from those of the normal testis. Both vasa defferentia were present, but not functional, and a well-developed but juvenile oviduct was present on the left side. Mr. Goodale has repeated this experiment, which seems well calculated to demonstrate the essentially hermaphrodite nature of the female fowl.

From some Brown Leghorn males of the age of three weeks testes were removed by Mr. Goodale. All developed the usual secondary male characters of plumage and spurs. The comb, on the other hand, developed far less than on the hen of the same race, so that the small comb of the capon can hardly be considered a female character. The crowing and mating instincts also are lacking.

Spurred Hens.—Spurs are secondary sex characters of cocks. Occasionally they are found even on young hens. In order to learn if the tendency to hen-spurring is inherited, three such hens were mated, by Mr. Goodale, to a cock that belonged to the same strain as one of the hens. Though the progeny are still too young to show spurs, the positive result has been gained that a hen with spurs need not differ, in point of fecundity and full development of maternal instincts, from ordinary non-spurred hens.

SEX IN MOLDS.

To broaden our knowledge of the phenomena of sex, Dr. A. F. Blakeslee, botanist at the Storrs Agricultural Experiment Station, well known for his researches in sex of the molds, has been granted leave of absence from

that station to carry on his work here as Research Associate. At present he is working to discover which of the sexual races of the mucors, provisionally designated by the terms (+) and (—), is actually male and which female. The effect of varying external conditions upon the sex, the form and physiology of the individual races, and their influence in inheritance will be tested. He reports that of the mucors he has under cultivation 8 hermaphrodite species and the paired strains of some 22 diœcious species, besides individual unmated races of a considerable number of other species.

HEREDITY OF OTHER CHARACTERISTICS.

Heredity of Flower and Foliage Colors.—Dr. Shull reports interesting studies in two species. In *Lychnis* the announcement of the discovery of a "dominant white" was premature, as the second hybrid generation proves that this white was a recessive white which was mated to unsuspectedly impure stock. The hopes expressed in the last report of being able to secure purebred purple-flowered strains from the reddish series have been realized. A "homozygous" or purebred "tinged white" strain has been produced; a number of different grades of greenness in foliage have appeared, indicating distinct biotypes; and variegated forms have arisen whose inheritance is being studied. The component color elements involved in the Shirley poppy have been isolated and some colors have been produced which are not visible in the original stock.

Heredity of Pitcher-leaved Ash Trees.—In studies in heredity with plants, garden or domesticated varieties have been largely employed and the characters studied have largely arisen under culture. But this is quite natural, since only the cultivated plants are best known; however, it has been raised as a criticism of modern studies. Studies are now being made by Dr. Shull on a striking character that occurs in a group of ash trees found in the forest near by, namely, the cornucopia-like folding of the terminal leaflet. He has bred trees having this character to themselves and to "normals" and has got from the first kind of cross some seedlings that already show the foldings; but none from the second kind of cross.

The Aberrant Inheritance Ratio of Bursa.—In continuation of his studies on this subject Dr. Shull finds that of the two hypotheses formulated to account for the unexpected inheritance ratios in the second hybrid and later generations of the cross between the flat capsuled and the elliptical capsuled bursas, the first is confirmed, the other must be rejected. The triangular capsule is independently produced by two different determiners, and the theoretical ratios of 15 : 1 in the F_2 generation and of 15 : 1 and 3 : 1 in the F_3 generation are to be expected. The hypothesis of the relative inefficiency of the *heegeri* type of fertilized egg is rendered untenable by the fact that families have appeared with an excess of *heegeri* offspring. The deviations from the expected ratio of 15 : 1 is accounted for on the hypothesis of a selective fertilization producing the observed excess of triangular capsules. The hypothesis is to be tested.

Variation and Hybridization in Evening Primroses (Oenothera).—The series of cross and self fertilized strains of *Oenothera lamarckiana* and certain of its derivatives have been continued by Dr. Shull, and special attention has been given to the offspring produced by several mutants from *O. gigas* and *O. rubrinervis*. A striking variegation in which the leaves have a yellowish-green central region surrounded by a dark-green margin is found to be slightly inheritable. The first plant of this sort was found last year. During the past season a second type of variegation has appeared, which is probably closely related to that first discovered, but has the central region of the leaf dark-green and the margin yellow. The latter kind of variegation has appeared on three different individuals of quite independent origin, and in two of the three plants the two sorts of variegation occur on different portions of the same plant. It is anticipated that this second type of variegation will differ very materially from the first in the extent to which the offspring will be affected.

Reciprocal crosses among three biotypes of *Oenothera cruciata* and between these three biotypes and *O. lamarckiana* have yielded a remarkable series of F_1 hybrids, the reciprocal families being in every case unlike, and many of the progenies being polymorphic. The latter consist of two or four distinct types. In several of the combinations a uniform progeny results when one of the biotypes is the seed-parent and a dimorphic or tetramorphic progeny when the other is the seed-parent. An interpretation of these anomalous results may be found only by carefully following each of the hybrid types through the second and probably later generations.

Relation between Heredity and Environment in Corn.—Dr. Shull has produced purebred strains of maize that vary greatly in quantity of yield. If a high-producing and a low-producing strain be crossed, the second hybrid generation gives offspring that show great variability in yield. Now, while under good conditions and poor conditions the *absolute* yield is different (environmental differences), under both conditions there is the same *relative* variability in the yield among the progeny of this F_2 generation (hereditary differences).

Inheritance of Light Reaction in a Parthenogenetic Species.—The theory that selection within the "pure line" is without effect should, obviously, apply to parthenogenetic species. And it is important to know if it holds for physiological characters as well as morphological. So Dr. Banta set himself (November 1911) to the task of testing the hypothesis that selecting within a "pure line" of daphnids the most and the least sensitive to light will not result in producing more or producing less light-sensitive strains. These lines have now (August 31) entered from the twentieth to the twenty-third generation. The material is favorable, inasmuch as the organism is prolific and new generations appear in rapid succession. Under the most favorable conditions a brood of young is sometimes produced by an individual when only 7 days old; and one and the same female may produce successive broods

at intervals of from 3 to 8 days, until from 4 to 8 broods appear of from 6 to 30 young each. At the last test the individuals of the strain originating in a sensitive mother reacted to light more quickly, and with more uniformity, than did those of the other strain.

Large vs. Small Feathered Chicks.—Certain strains of chicks have gained large quill feathers at 10 days after hatching, while these feathers are then relatively slight in other strains. A study of crosses between these two strains during two generations warrants the conclusion that well-developed wings and tail at 10 days is a condition recessive to ill-developed, though dominance of the great-feathered condition is by no means complete. (Goodale.)

Plumage Coloration in Ducks.—Data are being collected on inheritance of various white spots and "plain" head, black, heterochromidia, irides, red breast in the male, and spotting, not white. (Goodale.)

Hybridization of Butterflies.—Prof. John H. Gerould, of Dartmouth College, is continuing his experiments in hybridizing butterflies in association with this department. He reports that his attempts to hybridize *Papilios* were checked by certain technical difficulties but that he was quite successful in getting hybrids between two species of the cabbage butterfly, *Colias,* and he has fertile eggs laid by the hybrids.

STUDIES IN HUMAN HEREDITY

Through the continued support of Mrs. E. H. Harriman, to which has been added during the past year that of Mr. John D. Rockefeller, your Director has been put in a position not only to continue the work of the Eugenics Record Office, with its loyal staff, but to bring several of its studies to publication. Two of these deal with the detailed history of the matings and progeny of "degenerate" rural communities. They have important social bearings, and, from the scientific point of view, test the theory of inheritance of "feeble-mindedness," epilepsy, "shyness," indolence, and lack of self-control in the sex sphere. They discuss the relative rôle of "blood" and culture in such communities, using three criteria: (1) a comparison of the sets of children from two successive consorts of one parent; (2) a comparison of the behavior in later life of sibs who have been "placed out" or adopted in good homes with those who have remained under home culture; (3) a comparison of the behavior of the descendants of those who have moved to a distant State with cousins who have remained behind. By all these criteria the indelible impress of family traits under whatever conditions of culture is striking.

To facilitate the work of collecting data and of indexing them at the Eugenics Record Office, it became necessary to prepare a list of human "traits." This consumed a good deal of time, as apparently nothing of the sort had been attempted before. It will be an easier task to make the improvements and additions that future experience may require.

Inheritance of Human Skin-color.—As an apparent case of blending, the inheritance of skin-color in crosses between whites and negroes has commanded much attention. With the aim of extending studies published some years ago, a field worker of the Eugenics Record Office was sent to Bermuda to collect data; and later the Director of this Department visited Jamaica and secured cooperation for studies upon some 80 families. All determinations of skin-color are made quantitatively by means of the "color-mixer." Altogether data on over 125 families have been secured, with clear evidence that the skin-color of negroes depends upon two gametic factors for black pigment. This conclusion immediately explains all of the observed gradations of skin pigment in "colored" persons of all grades; demonstrates that wholly white-skinned persons may arise even in the second generation from negro parents, and proves that skin-color is no exception to the law of segregation of determiners in the germ-cells.

STUDIES ON TERATOLOGICAL VARIATIONS.

Teratological conditions are relatively so rare that there have been few studies made upon the laws of their occurrence, degree of development, and inheritance. Dr. Harris is dealing with large numbers for such studies. He has examined about 500,000 seedling beans and nearly 200,000 fruits of *Passiflora*. The abnormalities found are being studied and analyzed.

QUANTITATIVE STUDIES OF SELECTIVE ELIMINATION.

Material progress in this subject has been made by Dr. Harris, working with various flowering plants. Working with the physiological characters of fertility, fecundity, and seed-weight, and asymmetry, he has used them to study unfitness for survival. He finds that small and large seeds have about the same chance of developing to maturity in the field, but in neither case is the chance so good as for the seeds of more intermediate weight. He sought an answer to the question: Have abnormally shaped seedlings an equal chance of developing to maturity with normals? This involved the examination of over 200,000 seedlings and the planting of 5,030 normals and 4,217 abnormals. The answer was: There is a relatively high elimination of the abnormals. In further studies it is hoped to test the relative elimination of each type of abnormality.

INFLUENCE OF STARVATION OF PARENTS UPON CHARACTERISTICS OF PROGENY.

Dr. Harris has published in the June (1912) number of the *American Naturalist* a first study on this subject, based on many thousands of bean plants. Beginning with very similar seeds, of as nearly as possible similar potentialities, he planted some in poor soil and others in good soil; gathered the seed from the two lots, and, the next year, planted them side by side in a different, fairly fertile field. In another set of experiments two generations

were starved and well fed respectively before being grown in the comparison field. The conclusion is: there is no conspicuous influence of the different treatment of the ancestry upon the number of pods produced per plant.

EXPERIMENTS ON FEEDING EXTRACTS OF "DUCTLESS GLANDS."

Because of the importance of the testis in controlling the development of certain characteristics of the male sex, the question of possible control of bodily form or function by other glands which yield internal secretions becomes of importance. Dr. F. E. Chidester, of Rutgers College, started some investigations of this topic at the station during the summer of 1912. He fed rabbits and guinea-pigs both thyroid and thymus extract (desiccated) in daily doses of 0.4 to 2 grams. Even the smallest amount (0.4 to 0.6) of thyroid fed to pregnant rabbits caused extreme diarrhea and rapid heart action, and led to weak offspring, and soon killed even normal young nursed by the drugged mother. But feeding suprarenalin (0.5 to 2 grams daily) to non-pregnant rabbits was accompanied by steady increase of weight. Fowls similarly dosed with thyroid or thymus extract were not affected by diarrhea, palpitation of the heart, and falling of the hair like the rabbits.

STATISTICAL SUMMARY.

Poultry.—Of chicks 3,530 were hatched and of ducks 163.

Finches.—Of canaries about 80 were hatched, of which 50 survived infancy.

Sheep and Goats.—Twenty-six sheep were born and no goats.

Plants.—The number and extent of cultures grown in connection with Dr. Shull's investigations during the past year are indicated by the following table:

Name of species.	No. of families.	No. of individuals.
Agrostemma githago	1	18
Bursa bursa-pastoris	3	262
Bursa bursa-pastoris × heegeri F_2	3	379
Bursa bursa-pastoris × heegeri F_4	65	13,009
Camelina sativa	1	4
Fraxinus pennsylvanica	2	416
Lychnis cœli-rosa	3	74
Lychnis dioica	276	17,418
Lychnis dioica × coronaria F_1	2	4
Lychnis haageana	1	31
Lychnis noctiflora	4	293
Meconopsis heterophylla	1	36
Oenothera biennis	1	125
Oenothera cruciata	10	1,489
Oenothera cruciata × lamarckiana F_1	3	254
Oenothera gigas	3	214
Oenothera lamarckiana	21	1,285
Oenothera lamarckiana × cruciata F_1	3	151
Oenothera lamarckiana × rubrinervis F_1	1	85
Oenothera lata × lamarckiana F_1	1	85
Oenothera nanella	1	62
Oenothera rubricalyx	1	3
Oenothera rubrinervis	9	2,511
Oenothera sp. ?	1	21
Papaver commutatum	2	97
Papaver glaucum	1	132
Papaver glaucum × rhœas F_1	2	62
Papaver rhœas	31	3,020
Papaver rhœas × californicum F_1	1	1
Papaver rhœas × commutatum F_1	1	14
Papaver rhœas × glaucum F_1	2	127
Papaver somniferum	3	176
Papaver somniferum × californicum F_1	3	141
Papaver somniferum × commutatum F_1	1	14
Papaver somniferum × nudicaule F_1	1	1
Silene antirrhina	1	48
Silene vulgaris	2	48
Solanum guineense	1	16
Solanum guineense × villosum F_1	1	16
Solanum nigrum	1	16
Solanum villosum	1	16
Vaccaria vaccaria	1	18
Zea mays	126	7,810
Total	599	50,002

STAFF.

The staff remains as last year, except that Dr. A. F. Blakeslee, of Storrs Agricultural College, has accepted an invitation to associate himself with the Station for one year to carry on work in mutation and sex-control. Dr. F. E. Chidester, of Rutgers College, worked upon the effects of feeding extract of the ductless glands on the development of mammals. During the summer Dr. Shull was faithfully and efficiently assisted by Mr. William F. Friedman in making scientific records and in pollinating Indian corn.

CONSTRUCTION AND EQUIPMENT.

The animal house which was started last year was duly completed and was occupied during the summer for breeding the small mammals required for certain physiological and chemical studies. The chemical laboratory was moved to the upper floor of this building, which has been fitted up for the purpose. Attention is again called to the crowded condition of the present building. At the suggestion of the Trustees plans have been prepared for completing this building, which is to take care of all our small animals, including the Whitman pigeons which are to come to us. Certain new directions of work require the control of conditions which can not be furnished in the present building. New needs arise with the development of our science which require additional equipment.

The other principal piece of construction of the year has been a new house for young chicks, relieving the greenhouse, formerly so employed, for plant work. This building, 80 by 20 feet, is built of concrete blocks covered with stucco, and provides for 15 runways. The work of fencing the station farm, using concrete posts, has been started.

GEOPHYSICAL LABORATORY.*

Arthur L. Day, Director.

The present year has witnessed the close of two investigations of considerable magnitude, both of which are intimately associated with nearly every problem hitherto studied in the laboratory.

The purpose of the first† was to place the methods for the study of minerals with the petrographic microscope upon a quantitative basis, so far as practicable. If we would study these matters precisely, we must have not only an indication of what happens when minerals are brought into combination, but a definite numerical measure of the properties which are characteristic of the resulting substance and which serve to distinguish it from the initial ingredients.

The purpose of the second‡ was to perfect the apparatus and methods for the accurate measurement of those extreme temperatures where the minerals enter into combination. Supposing the chemical composition to be known, two conditions suffice to define and to reproduce all that occurs when two minerals are brought together—the pressure and the temperature. Methods for measuring extreme temperatures with the highest accuracy are now provided; of the measurement of pressure more will be said farther on.

The Use of the Microscope.—It happens that the work with chemically pure silicate preparations (mineral types) has imposed new and difficult problems to be solved by the microscope. Not only are such preparations very fine-grained, but the quantitative character of the studies now being undertaken imposes wholly new standards of accuracy for each measurement. To meet these new conditions, it has been necessary to devise new methods involving extensive alterations in the microscope, and also to test the existing methods for the determination of the optical constants of minerals in thin sections. The effort has been made to establish the limits of accuracy of each method and also the limits of accuracy theoretically attainable in measurements of this kind. As a general result, it may be stated that on clear individual grains measuring from 0.01 to 0.03 mm. in diameter, all the optic properties ordinarily studied in the microscopic investigation of minerals in the thin section can now be determined with a satisfactory degree of accuracy. This investigation, which has been of the most thorough-going character, has occupied six years, and its results are now available to all students of petrology. Some of the methods have already been adopted abroad and are finding a wide field of usefulness.

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* Situated in Washington, D. C. Grant No. 744. $75,000 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 3–10.)

† Publication of the Carnegie Institution of Washington No. 158.

‡ Publication of the Carnegie Institution of Washington No. 157 and Am. J. Sci. (4), 33, 517–533. 1912.

High Temperature Measurement.—The second investigation was concerned with the attainment of means for the more accurate measurement of temperatures, beginning with the low temperatures of every-day life and extending upward to the melting-points of the most refractory metals and oxides. In this investigation, also, it has proved practicable to increase the accuracy of measurements of high temperatures considerably—perhaps tenfold—and to provide a temperature scale of most trustworthy character in terms of which the temperatures where the various component minerals of the earth are stable can be accurately determined and expressed. The high-temperature portion of this scale was completed a year ago and is already in use; but the lower temperatures (300° to 650° C.) have been redetermined during the present year with especial care in order to meet the more exacting requirements of certain investigations which have been undertaken at these temperatures. The accuracy now attainable in temperature measurements in the vicinity of 500° C. is perhaps $\pm$ 0.1°; in the region about 1500° C., perhaps $\pm$ 2.0°.

High Pressure Measurement.—Following these two completed investigations, which are of vital importance to all the studies thus far undertaken in this laboratory, it remains to speak of the third: the problem of the accurate measurement of extreme pressures. It is but a few years since all measurements of very high pressures were inseparably bound up with such factors as the friction of pistons, the viscosity of the transmitting medium, and other mechanical factors which sometimes affected the final result by as much as 30 or 40 per cent. Through the recent efforts of Tammann of Göttingen, of Bridgman of Harvard, and of some others, these uncertain factors have been gradually disappearing, and it is now possible to obtain measurements even of very high pressures with no error greater than that which obtains in the measurement of high temperatures noted above, provided the temperature which prevails in the apparatus is not far above or below the temperature of the surroundings. It is just here that our peculiar difficulties arise, for practically all applications of high pressure in the study of the mineral relations require the simultaneous application of high temperature, and no containing vessel is known which can withstand extreme pressure when hot.

Investigation along these lines has proceeded but slowly on account of the serious technical difficulties involved in such work, but it is now possible to report that many of these obstacles have at last been overcome, so that a more rapid rate of progress in the future seems assured. Limitations of space prevent more than a mere reference to these obstacles; the sentences following will serve to indicate some of the points in which progress has been made and to show that the accessible range of pressure and temperature has been extended and the accuracy of measurement improved.

In the report for 1911 (Year Book No. 10, p. 95) there was given in abstract an account of work in which temperatures up to 400° and pressures up to 2,000 atmospheres (30.000 pounds per square inch) were employed;

the temperatures were measured with a precision of about 0.02°, the uncertainty in the pressure measurements was about 5 atmospheres. In order to insure accuracy in the measurements of pressure, an absolute gage has been constructed. With this instrument, the principle of which is that the pressure acting upwards on a known area is balanced directly by the use of a series of weights, pressures up to 1,000 atmospheres can be measured with an absolute accuracy of 1 part in 1,000, while its sensibility, even at that pressure, is such that differences considerably less than 1 atmosphere can be detected. This gage and another on the same principle designed for weighing still higher pressures are to be used to calibrate secondary gages, which then, in the actual investigations, will be convenient and accurate to use.

In the work alluded to above we were limited to temperatures about 400° and to pressures about 2,000 atmospheres. These limits have now been extended—separately at least—by the construction of a bomb capable of withstanding 2,000 atmospheres, but so constructed that a temperature of 1000° or more can be reached and maintained for as long a time as may be desired; while on the pressure side a multiplying arrangement has been completed which will enable us to develop and control pressures up to 5,000 atmospheres (75,000 pounds per square inch). Incidentally to this work, types of valves and pressure connections have been developed which can, as often as necessary, be taken apart and put together again, and yet show no signs of leak even at the highest pressures. Though but a technical detail, this device is of vital import to the ultimate success of the investigation.

A survey of the literature pertaining to the effects produced by the action of high pressure on solids at ordinary temperatures revealed a number of outstanding discrepancies and uncertainties, some of which we were able to eliminate by a critical study of the recorded results and of several series of original observations. These discussions have been published and are abstracted on a later page.

Bombs Containing Water.—Closely allied to the investigation of those problems in which pressure is of prime importance is another field, namely, the investigation of the behavior of minerals in contact with water or aqueous solutions at moderately high temperatures (up to 500°). Vessels used in such work must be capable of withstanding considerable pressures without sensible leak in order to avoid loss of the volatile component. Here, again, the technical difficulties are considerable, but many of them have now been successfully obviated. A systematic experimental survey of this field has been undertaken and considerable work in this direction has already been accomplished; but it has not proved possible yet to formulate from it any definite conclusions of general application.

Quartz and Other Forms of Silica.—Turning now from these investigations, which are mainly directed toward the perfection of the implements of research and upon which the quality of the results attained very largely de-

pends, we may pass in rapid review some of the mineral studies now in progress. Of these the investigation of the various forms of pure silica and their relation to each other is perhaps the oldest.

Silica is the most common and widely distributed ingredient in all of our rocks. It is therefore of first importance to know the precise conditions under which it crystallizes. This is the more necessary because it occurs in so many different crystal forms—at least seven, known to mineralogists by the names quartz (two forms, α and β), tridymite (α and β), cristobalite (α and β), and chalcedony—and neither the relations between these nor the conditions of their formation are known.

In one of the earlier papers from this laboratory evidence was offered that quartz, when heated to about 800°, goes over (without melting) into another crystal form, tridymite (or cristobalite), albeit very slowly even in the presence of a liquid flux which greatly increased its molecular mobility. It is also known that quartz itself undergoes a change of crystal form (α to β) at 575°, this change being very prompt in its appearance and sharp. Both changes are reversible. It was furthermore found, by reason of the extremely sluggish behavior in the vicinity of 800°, that the low-temperature form (quartz) could exist for a considerable time at temperatures higher than 800° and that the high-temperature forms (tridymite and cristobalite) if cooled quickly down past this temperature could exist indefinitely at ordinary temperatures in spite of the tendency to change to quartz.

Continuing this investigation, we now find further that under more favorable conditions the temperature of the sluggish change from quartz to tridymite is very near 870°, and that tridymite and not cristobalite is the stable form above 870° as far as 1470°, where tridymite (also without melting) goes over into cristobalite. Further heating melts the cristobalite very slowly, beginning at 1600° C. The change from tridymite to cristobalite at 1470° is also reversible. From these observations it appears that it is not strictly correct to speak of the melting-point of quartz, as is frequently done. Quartz normally* passes through three different modifications (β-quartz, tridymite, and cristobalite) before reaching the melting temperature, and finally melts as cristobalite. It has been previously noted that when tridymite and cristobalite are quickly cooled past the inversion temperatures they may be cooled to ordinary temperatures (where quartz alone is stable) without reverting to quartz. It does not follow that they do so unchanged. Although neither can be persuaded to revert to the form stable at these low temperatures, each undergoes a further and definite change of crystal form. Tridymite inverts (β to α) at 117° (reversible), and cristobalite (β to α) at a temperature (205° to 275°) variable with certain experimental conditions which are not yet cleared up (also reversible). Chalcedony, on the other hand, though of identical chemical composition, shows no change whatever when

* In the comparatively rapid heating necessary in all laboratory work these steps may not all occur in each instance.

heated to 575°, and therefore differs from quartz, but it goes over into tridymite like β-quartz at 870°, after which its behavior is that of normal tridymite. The conditions of its formation are not yet known.

All these forms of silica are readily identified, and some at least leave a more or less perfect record of the changes through which they have passed. They are thus of considerable assistance to geologists in determining the succession of temperatures in given geologic processes.

Portland Cement.—Next to silica in point of seniority is the investigation of the conditions of association of the three oxides—lime, alumina, and silica—three of the commonest components of all igneous rocks and incidentally the three chief ingredients of artificial building-stone (Portland cement).

The purpose of these studies, whether considered in relation to natural rocks or to artificial cements, was to ascertain:

(1) All the compounds of these three ingredients which are possible.
(2) The temperatures within which each of these compounds is stable and therefore capable of independent existence.
(3) The relation between each compound and any or all of the others at whatever temperature.
(4) The behavior of these individual compounds or groups of them in the presence of water at various temperatures.
(5) The application of this information to the study of natural rocks or to the making of artificial rocks (cements).

The first three of these studies include the major portion of the labor and are now practically completed, (1) and (3) are in fact already published, (2) will appear in print early in the coming year, and (4) is now being actively prosecuted; (5) is not altogether within the province of the laboratory, but it is our purpose, at the close of the investigation, to indicate the more important applications of the information obtained which chance to be within our experience.

Mineral Sulphides.—To the paper of a year or more ago on the mineral sulphides of iron has now been added a second contribution to the elucidation of the general question of the conditions of formation of the sulphide ore-bodies which contribute so largely to our mineral wealth. The study of the sulphides of iron served to clear up the long-mooted question of the true composition of and relation between pyrite, marcasite, and pyrrhotite and the conditions favorable to their formation. The paper on "The Sulphides of Zinc, Cadmium, and Mercury, their Crystalline Forms and Genetic Conditions" (reviewed on p. 106) extends the inquiry to three new groups of sulphides and reaches equally definite conclusions. It is now proposed to continue on to the sulphides of copper and eventually to those of lead. It is probable that in these latter groups the relations are somewhat more complicated than those hitherto studied, but their importance is very great.

Mineral and Rock Densities.—Something over three years ago a method was developed in the laboratory for the convenient measurement of the density of minerals and rocks at high temperatures. Comparisons of density are commonly made at 0° or at 25°, but such determinations give little information through which to compare densities, for example, at the temperature of formation. In fact, throughout geological literature there is a constantly recurring doubt as to whether, at the temperature of formation, a solid mineral or rock is heavier or lighter than the molten mass out of which it crystallized. With this new apparatus it is possible to make a continuous series of measurements of density, upon small rock or mineral samples, from comparatively low temperatures up to and beyond the melting-point, with considerable accuracy.

This is not a favorable opportunity to take up in detail the behavior of the various minerals which have been studied in this apparatus, but a situation has been developed through these experiments which is of considerable significance to geologists. When a mineral or rock sample is heated, it almost invariably begins to give off gas at about 900°, and may continue setting free volatile material up to 1400° or 1500°. The disposition of the gas for the purposes of this measurement offers no difficulty, but the interpretation of the results becomes a somewhat complicated matter. The volume to which the rock returns after the gas is set free is not identical with the initial volume, nor is its expansion under these conditions an independent function of the temperature. It follows that density determinations made at high temperatures, but at ordinary atmospheric pressure, do not reproduce the conditions which obtain during rock formation in nature, even though the temperatures and the composition of the solid ingredients are the same. This may serve as a further reminder that, in the general consideration of the physical and chemical behavior of rocks and minerals in nature, regard must be had for the volatile ingredients which participated in their formation, whether or not portions of these have escaped either at the time of formation or subsequently. Neither the physical and chemical properties of a rock nor its relation to its neighbors remain the same after the volatile but chemically very active ingredients have departed.

Volcano Studies.—In pursuance of a plan which was approved last year for the study of the physics and chemistry of active volcanoes, the Director and one member of the laboratory staff spent three months of the past summer in studying the active crater Kilauea, on the Island of Hawaii. Of the results little can be said until an opportunity has been given for a detailed study of the products of volcanic activity which were collected and brought to Washington for this purpose. In confirmation of the fact above mentioned, that the volatile ingredients have played a much more active part in rock formation than has hitherto been attributed to them, it may be noted that systematic observation has shown that the lava temperature within the active basin is not constant, but varies within considerable limits from day to day,

and that the changes appear to be governed entirely by the quantity of gas which is set free. In other words, when the quantity of lava within the basin remains practically constant, but the quantity of gas given off increases considerably, there is a considerable rise in the temperature corresponding to it; and similarly, when the quantity of gas again diminishes, the temperature falls appropriately. Inasmuch as these observations at the crater are still going on, exact figures are not yet available. It proved practicable to descend into the crater, to collect a considerable quantity of the gas as it emerged from a fountain of liquid lava, to seal it away in glass tubes without its having come in contact with the air at all, and to transport this gas to Washington safely, for detailed study. It is also practicable to ascertain the composition of the smoke cloud, which contains considerable matter which is not gaseous. Samples of the liquid lava taken directly from the lava lake were obtained last year. With this material we entertain the hope that it will prove practicable to determine the character of the chemical reactions within the gases, between the gases and the liquid lava, and between the gases and the air. If this can be done, considerable light will be thrown upon the character of the chemical reactions which participate in the activity of this particular volcano. In view of the fact that several recent writers have sought to prove that water has no part in volcanic activity, it may be mentioned that out of the gases which we collected directly from the boiling lava something like a half pint of water condensed in the tubes on cooling.

Brief reviews of the papers published by members of the laboratory staff during the current year follow:

(1) Ueber den Durchgang des Lichtes durch inaktive durchsichtige Krystallplatten mit besonderer Berücksichtigung der Erscheinungen im konvergent polarisierten Lichte. Fred. Eugene Wright. Tschermak's Min. Petrogr. Mitt., 30, 171–232. 1911.

A German translation of "The transmission of light through transparent inactive crystal plates, with special reference to observations in convergent polarized light" (Am. Jour. Sci. (4), 31, 157–211, 1911). Reviewed in Year Book No. 9 (1910), p. 100.

(2) On powers of ten. Walter P. White. Science, 35, 38–40. 1912.

Physical magnitudes, as written, usually consist of two parts, the significant figures and a power of 10. Ordinarily, all powers of 10 are liable to be used. If restriction is made to those powers which are also powers of 1,000, as is now done by many writers, greater uniformity is secured among different writers, confusion is less likely, and the memory is aided, since in most cases there is no doubt which power of 1,000 is the right one. Numbers are still more readily comprehended and remembered if the power of 1,000 is indicated by a word, such as one of the prefixes milli, mikro, kilo, mega. These prefixes, however, can only be used in connection with units having names (*e. g.*, megadyne, mikrovolt, millimeter); it is greatly to be desired that some convention should be established by which they could also be used for such quantities as expansion coefficients, degrees of precision, etc.

(3) Die mineralischen Eisensulfide. Von E. T. Allen, J. L. Crenshaw, und John Johnston; mit kristallographischen Untersuchungen von Esper S. Larsen. Z. anorg. Chem., 76, 201–273. 1912.

A German translation of "The mineral sulphides of iron" (Am. Jour. Sci. (4), 33, 169–236, 1912). Reviewed in Year Book No. 10 (1911), p. 104.

(4) Beitrag zur Untersuchung der Portlandzementklinker. Über die hypothetische Verbindung $8CaO.Al_2O_3.2SiO_2$. Von G. A. Rankin; nebst optischen Untersuchungen von Fred. Eugene Wright. Z. anorg. Chem., 75, 63–66. 1912.

In this paper, experimental evidence is offered that the hypothetical compound $8CaO.Al_2O_3.2SiO_2$ suggested by Jänecke (Z. anorg. Chem., 73, 200, 1911) has no independent existence, but consists in fact of a mixture of three compounds, in accord with the previous publication from this laboratory ("Preliminary report on the ternary system $CaO–Al_2O_3–SiO_2$; a study of the constitution of Portland cement," J. Ind. Eng. Chem., 3, 1–43, 1911). At ordinary temperatures (below 1404°) the mixture is made up of $3CaO.SiO_2$, $2CaO.SiO_2$, and $3CaO.Al_2O_3$. Neither the composition $8CaO.Al_2O_3.2SiO_2$ nor any other composition approximating to it shows any new phase which is not described and identified in the previous paper on the ternary system, lime-silica-alumina (reviewed in Year Book No. 10 (1911), p. 92).

(5) The nitrogen thermometer scale from 300° to 630°, with a direct determination of the boiling-point of sulphur. Arthur L. Day and Robert B. Sosman. J. Wash. Acad. Sci., 2, 167–176. 1912.

A preliminary publication of results contained in the following paper:

(6) The nitrogen thermometer scale from 300° to 630°, with a direct determination of the boiling-point of sulphur. Arthur L. Day and Robert B. Sosman. Am. Jour. Sci. (4), 33, 517–533. 1912.

In the publication of the authors' investigation upon the absolute measurement of high temperatures ("High temperature gas thermometry," Publication of the Carnegie Institution of Washington No. 157, 1911), the following paragraph occurs (p. 125):

"The chief source of present uncertainty [in high temperature gas-thermometer measurements] is the temperature distribution over the surface of the bulb in an air-bath. It would be possible to eliminate this error in the lower portion of the scale by substituting a liquid-bath which could be stirred. In fact, this was done for temperatures below 500° in the earlier work of Holborn and Day, but has not, so far, been tried in the present investigation because of the relatively secondary importance of the lower temperatures to the ultimate purpose of the investigation (the study of silicates). For the higher temperatures, no satisfactory liquid-bath has been found."

The lower temperatures upon this scale, determined in an air-bath, come out about 1° lower than the corresponding temperatures of the Reichsanstalt scale (determined in a liquid-bath).

In certain studies now under way in this laboratory on the effect of pressure upon equilibria, greater accuracy is now required in the measurement of these particular temperatures than had previously been necessary. We therefore determined to repeat these measurements (up to 650°), with more elaborate precautions to secure a uniform temperature about the bulb, this being, as stated above, the one factor in our measurements about which some uncertainty remained. The results are contained in the following table:

Point.	Temperature.		Notes.
	Const. vol. $P_0=1$ at.	Thermo-dynamic.	
Benzophenone (Kahlbaum), boiling-point at 760 mm.	305.85	305.9	Transferred by platin-rhodium and copper constantan thermo-elements.
Cadmium, melting-point	320.8	320.9	Interpolated.
Zinc, melting-point	419.3	419.4	Transferred by thermo-elements.
Sulphur, boiling-point at 760 mm.	444 40	444.55	Direct.
Antimony (Kahlbaum), melting-point	629.8	630.0	Transferred by thermo-elements.
Aluminum, melting-point	658.5	658.7	Interpolated.

(7) Die Stickstoffthermometerskala von 300–630° und eine direkte Bestimmung des Siedepunktes des Schwefels. Arthur L. Day und Robert B. Sosman. Ann. Physik, 38, 849–869. 1912.

A German translation of "The nitrogen thermometer scale from 300° to 630°, with a direct determination of the boiling-point of sulphur" (Am. Jour. Sci. (4), 33, 517–533, 1912). Reviewed under No. 6 above.

(8) A note on the standard scale of temperatures between 200° and 1100°. L. H. Adams and J. Johnston. J. Wash. Acad. Sci., 2, 275–284. 1912.

A preliminary publication of the results described in paper No. 9:

(9) A note on the standard scale of temperatures between 200° and 1100°. L. H. Adams and J. Johnston. Am. Jour. Sci. (4), 33, 534–545. 1912.

In this note is given a new calibration curve for copper-constantan thermo-elements, extending from 0° up to 360°, together with a series of independent measurements of the temperature differences between the boiling-points of naphthalene (217.95°) and benzophenone (305.9°) on the one hand and the freezing-points of tin, bismuth, cadmium, and lead on the other. These measurements lead to the following values of the freezing-points: Sn, 231.8°; Bi, 271.0°; Cd, 320.9°; Pb, 327.3°. The concordance of these values with those obtained by other measurements show that the thermo-element is not inferior to the resistance thermometer within this range of temperature (0° to 360°). Moreover, a comparison of the gas-thermometer determinations with the results obtained by means of those interpolation instruments (thermo-element, resistance thermometer, etc.) which measure not temperature independently but a well-defined physical property which changes continuously with the temperature, affords an excellent opportunity, *through this continuity*, for the discovery of inconsistencies in the gas-thermometer measurements. The remarkable concordance of the present series of thermo-electric measurements and of the most extensive recent series of resistance-thermometer measurements (Bureau of Standards), with the recent gas-thermometer determinations made in this laboratory, serves, therefore, as an efficient and independent check upon the trustworthiness of the present gas-thermometer scale between 0° and 1100°.

(10) On the density of solid substances, with especial reference to permanent changes produced by high pressures. John Johnston and L. H. Adams. J. Am. Chem. Soc., 34, 563–584. 1912.

With a new and improved form of pyknometer the density of salts and other substances has been determined with an accuracy of 3 or 4 units in the fourth decimal place, that is, within 0.02 per cent. In many cases, however,

such accuracy is unnecessary, since the variations of density due to inhomogeneities of the material may be much greater than this.

Powdering a crystalline substance does not change its density by an amount which we can detect with certainty, provided that the material is homogeneous and free from cracks and holes; but if the substance is not homogeneous, then, as might be expected, the fine powder is denser than the coarse particles.

Neither does very high hydrostatic pressure produce any after-effect on the density of strictly homogeneous crystalline compounds.

But if the pressure be not uniform, then the density of a metal which has been subjected to such compression—or has been deformed in any other way—usually increases first (owing presumably to the filling up of pores and cracks) and then decreases, sometimes even so as to reach a final density less than the original value. Subsequent annealing of the specimen causes a renewed increase of density. The direction of the change of density on compressing bismuth is, contrary to Spring's conclusion, the same as that for other metals, namely, a decrease of density following upon deformation. The bearing of these results upon the question of the "flow" of metals is discussed: they are shown to be in harmony with the idea that the "flow"—or indeed any deformation—of a metal is a manifestation of a real melting produced by the unequal strains set up during the process.

Finally, it is important to emphasize the fact that the density of most substances is somewhat variable, owing to a lack of complete homogeneity of the material. In consequence of this, slight changes of density can not be regarded as good evidence for the occurrence of any transformation or chemical reaction, whether produced by subjecting the system to compression or by other means.

(11) Die Dichte fester Stoffe, mit besonderer Berücksichtigung der durch hohe Drucke hervorgerufenen dauerenden Änderungen. John Johnston und L. H. Adams. Z. anorg. Chem., 76, 274–302. 1912.

A German translation of "On the density of solid substances with especial reference to permanent changes produced by high pressures" (J. Am. Chem. Soc., 34, 563–584, 1912). Reviewed under No. 10 above.

(12) A correlation of the elastic behavior of metals with certain of their physical constants. John Johnston. J. Am. Chem. Soc., 34, 788–802. 1912.

This paper consists of a discussion of the idea that the "flow," or permanent distortion, of metals is conditioned by a real melting, not of the whole mass of metal at any one instant, but of successive groups of particles (namely, those on which the brunt of the strain momentarily falls). This idea serves to correlate some properties of metals which at first sight would appear to bear no relation to each other; it leads, namely, to the fact that there is a parallelism between all the elastic properties of metals for which quantitative measurements have been made and the pressure—assumed to act on the solid phase, but not, or not to the same extent, on the liquid phase—which is required to lower the melting-point to ordinary temperature. This pressure is a function of the melting-point, latent heat of melting, and density at the melting-point of the metal; hence, if these quantities are known for any substance, we can predict the relative order of magnitude of any of its properties which imply deformation of the material.

The same mode of reasoning is equally valid for any crystalline substance, and could be applied to all salts (including silicates and other geologically important substances) if the necessary data were available. At the present

time, values of the latent heat of melting are few and far between, so that no general discussion of this part of the subject is practicable now. This reasoning can not, however, be applied to glasses; for since they are merely supercooled liquids, the latent heat of melting is zero, and hence, according to the equation $\frac{dT}{dP}$, the change of melting-point with pressure is infinite. But this is not so contradictory as at first sight it may seem, for glasses behave as liquids of exceedingly high viscosity, provided always that, conformably with this high degree of viscosity, sufficient time be allowed for the motion to take place.

It has recently been established that a large number of apparently diverse physical properties of a substance—melting-point, specific heats, coefficients of thermal expansion and compressibility, electrical resistance—may be considered to be functions of a characteristic quantity, the molecular "vibration frequency." Now, the flow-pressure, according to the equation discussed in this paper, is a function of some of the above properties, and hence is a function of the "vibration frequency." The existence of such a relationship accounts simply for the parallelism between the calculated flow-pressures and the mechanical properties of metals, for all of these quantities are functions of the same characteristic parameter—a fact which indicates that all the mechanical properties of metals will be found to be periodic functions of their atomic weights, since the vibration frequency itself is doubtless such a periodic function.

(13) Eine Beziehung der elastischen Eigenschaften der Metalle zu einigen ihrer physikalischen Konstanten. John Johnston. Z. anorg. Chem., 76, 361–379. 1912.

A German translation of "A correlation of the elastic behavior of metals with certain of their physical constants" (J. Am. Chem. Soc., 34, 788–802, 1912). Reviewed under No. 12 above.

(14) The binary system: $Na_2Al_2Si_2O_8$ (nephelite, carnegieite)–$CaAl_2Si_2O_8$ (anorthite). N. L. Bowen. Am. Jour. Sci. (4), 33, 551–573. 1912.

The study of the system $Na_2Al_2Si_2O_8$–$CaAl_2Si_2O_8$ was undertaken because of the importance of these compounds as rock-forming constituents. It was found that the soda compound exhibits enantiotropism with the inversion point at 1248°. The low-temperature form (nephelite) crystallizes in the hexagonal system with a habit similar to that of natural nephelite. The high-temperature form is triclinic. It has no natural analogue and has been given the name carnegieite. Carnegieite melts at 1526°.

The lime compound occurs only in the triclinic form, anorthite, and melts at 1550°.

Both carnegieite and nephelite are capable of holding the lime compound in solid solution, the former 5 per cent and the latter as much as 35 per cent.

The effect of solid solution on the inversion-point was well shown by the system. The temperature of inversion rises considerably as the amount of the lime compound in solid solution increases.

The optical constants of the components were carefully determined. Crystals of the artificial nephelite were measured on the goniometer and their hexagonal nature confirmed. It was especially gratifying to be able to determine definitely the variation, with composition, of the optical properties of the hexagonal mix-crystals (nephelite). With increasing proportion of the lime molecule the birefringence of 0.004 (negative) becomes less, passes through zero, and finally becomes 0.002 (positive).

The problem as a whole, although in some measure complicated, was found capable of very definite laboratory solution. The extension of the study to include the potassium-bearing nephelites has already been begun.

(15) Mixtures of amorphous sulphur and selenium as immersion media for the determination of high refractive indices with the microscope. H. E. Merwin and E. S. Larsen. Am. Jour. Sci. (4), 34, 42–47. 1912.

Fused mixtures of sulphur and selenium are glassy when cold. By standardizing the mixtures with respect to their refractive indices by measurements on prisms molded into the angle between glass plates, they can be used to match the refractive indices of suitable substances immersed in them and studied under the microscope. A chart showing the refractive indices of various mixtures for several wave-lengths has been prepared, and a method of interpolating values of refractive indices, obtained by using a monochromatic illuminator, explained.

(16) Microscopical petrography from the quantitative viewpoint. Fred. Eugene Wright. Jour. Geol., 20, 481–501. 1912. (In press.)

In this paper attention is directed to the importance of good quantitative work in microscopical petrography which has now passed the qualitative, reconnaissance stage of its development and is entering upon large problems, essentially quantitative in nature, which require precise data of observation for their solution. The different optical properties used in the determination of minerals are classified in detail and simple effective methods are briefly described which experience has shown to be well adapted for the determination of the different optical constants of mineral plates and grains.

(17) Petrographic study of the specimens of loess, tierra cocida, and scoria collected by the Hrdlicka–Willis Expedition. Fred. Eugene Wright and Clarence N. Fenner. Included in the volume Early man in South America, by Ales Hrdlicka in collaboration with W. H. Holmes, Bailey Willis, Fred. Eugene Wright, and Clarence N. Fenner. Bulletin No. 52, 55–98 (1912), Bureau of American Ethnology, Smithsonian Institution.

This collection was found to contain several extraordinary rock types, and in approaching the problems which they present three distinct lines of attack were followed: (1) the usual detailed petrographic-microscopic examination of the rocks; (2) chemical study of the different rock types; (3) thermal study of the specimens at different temperatures and comparisons of the products thus obtained with the natural products.

The most important conclusions resulting from these three lines of independent evidence are:

(1) The *loess* consists in large measure of volcanic and eruptive material. Salic volcanic glass is present in practically every specimen and may become so abundant that it constitutes 90 per cent of the whole. The minerals are remarkably fresh and unaltered, while the amount of argillaceous material present is relatively small in most of the specimens. These facts may be considered indicative of tremendous and widespread volcanic activity of the explosive type during or just preceding the formation of the loess.

(2) The specimens of *tierra cocida* are composed, for the most part, simply of loess fragments which have been indurated and reddened by heat action, between 850° and 1050°. The loess and tierra cocida are similar in general character and composition.

(3) The *scoriæ* are not normal volcanic scoriæ. They have been produced by the melting down of an original clastic material (loess) under con-

ditions which protected the molten mass from oxidation. The hypothesis is advanced that the loess formation was intruded by igneous masses which melted down the adjacent loess and formed the present black scoriæ. The lack of oxidation of the scoriæ and their abundance in the field precludes the possibility that they were formed by the melting down of loess by bonfires or any type of fire in the open air. Prehistoric man is, therefore, not responsible for their occurrence.

(18) The expansion coefficient of graphite. Arthur L. Day and Robert B. Sosman. Jour. Wash. Acad. Sci., 2, 284–289. 1912.

A preliminary publication of the results of the investigation reviewed below (No. 19).

(19) The expansion coefficient of graphite. Arthur L. Day and Robert B. Sosman. J. Ind. Eng. Chem., 4, 490–493. 1912.

The expansion of artificial graphite up to 1500° was determined as a basis for the measurement of specific volumes of minerals and rocks at high temperatures. Two methods were used: (1) the expansion of a bar of graphite self-heated by a heavy current was measured by means of micrometer microscopes at a fixed distance apart; (2) the expansion of the same bar was observed in a platinum-resistance furnace. The mean coefficient from zero degrees is $0.55 + 0.0016\ t$.

The comparison of this value with other determinations on natural graphites and other forms of carbon shows a parallelism between the temperature of formation and the smallness of the coefficient, and indicates that the name "graphite" covers a continuous series of substances of varying properties.

(20) The sulphides of zinc, cadmium, and mercury; their crystalline forms and genetic conditions. E. T. Allen and J. L. Crenshaw. Microscopic study by H. E. Merwin. Amer. Jour. Sci., 4, 34, 341–396.

The sulphides of zinc are enantiotropic, with an inversion point at 1020°. Sphalerite is the stable form below this temperature, wurtzite above. Their indices of refraction, dispersion, and specific gravities were determined. Iron in the form of ferrous sulphide is present in solid solution in the ferruginous sphalerites, since the specific volume, index of refraction, and inversion-point change continuously with increasing percentage of iron. Sphalerite was formed synthetically by action of alkali sulphides on zinc salts at 200° and above. Wurtzite was obtained by action of hydrogen sulphide on solutions of zinc salts containing free acid at temperatures between 250° and 350°.

Only one crystalline form of cadmium sulphide was obtained. It is identical with the mineral greenockite. Crystallographic and optical measurements and determinations of specific gravity were made on a very pure synthetic preparation.

Besides cinnabar, a black sulphide of mercury, probably identical with metacinnabar, and a new form, hexagonal, but with properties distinct from cinnabar, were obtained. Cinnabar is the stable form; the other two are monotropic forms.

The most interesting result for geochemistry which was obtained in these synthetic studies was the following: The unstable crystalline forms, metacinnabar, wurtzite, and marcasite, are obtained only from acid solutions, while the corresponding stable forms, cinnabar, sphalerite, and pyrite, are the only product of alkaline solutions, though they may be obtained from acid solutions also.

(21) Die Sulfide von Zink, Cadmium und Quecksilber; ihre Kristallform und genetischen Beziehungen. E. T. Allen und J. L. Crenshaw. Mikroskopische Untersuchung von H. E. Merwin. Z. anorg. Chem., 1912.

(22) Mikroskopische Petrographie vom Quantitativen Standpunkt. Fred. Eugene Wright. Neues Jahrb. Min. Geol. (In press.)

A German translation of "Microscopical petrography from the quantitative viewpoint" (Geol., 20, 481–501, 1912). Reviewed under No. 16.

(23) Study of a contact metamorphic ore-deposit. The Dolores mine, at Matehuala, S. L. P., Mexico. J. E. Spurr, G. H. Garrey, and Clarence N. Fenner. Econ. Geol., 7, 444–484. 1912.

This is a study of an interesting problem in applied geology, toward which the laboratory contributed an exhaustive petrographic investigation of the various types of rock which had been collected in the field. The problem comprised the study and elucidation of the phenomena of an unusual type of metamorphism and ore-deposition, associated with and consequent upon the intrusion of a great mass of eruptive rock into a series of sedimentary beds. In conjunction with the field-work a collection of typical rock-specimens was sent to the laboratory. From these the field relations which had been observed were confirmed and supplementary information obtained. From the different sources of information thus made available it was possible to arrive at well-grounded conclusions regarding the geological history of events, including the sequence of mineral deposition, the nature of the circulating solutions, and the relations existing between the metallic sulphides and the gangue minerals.

(24) The various forms of silica and their mutual relations. Clarence N. Fenner. Jour. Wash. Acad. Sci., 2, 471–480. 1912.

The problem presented by the various forms of silica in their relations to each other has been the subject of some previous investigation by a number of experimenters. The results obtained have not been altogether concordant, and the present investigation was undertaken in order to reconcile or explain these discrepancies and to throw as much additional light as possible upon the subject. The great abundance of free silica in very diverse modes of occurrence in nature made it appear of some importance to secure such additional information. The investigation is not yet concluded, but the main relations have been established.

The inversion-point between quartz and tridymite has been located with considerable exactitude (at about 870°) and the best conditions for effecting the transformation have been determined. It has also been settled that the transformation is reversible. Similar information has been obtained regarding the transformation of tridymite into cristobalite (at about 1470°), and it has been established that the two are perfectly distinct minerals, each with a definite range of stability. It has been determined, however, that under certain conditions one form of silica may be produced within the field of stability of another, and some of the divergent results of previous investigators are thus explained.

The inversions of α into β tridymite and α into β cristobalite have also been studied by somewhat novel methods and the relation of these to the other transformations shown.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. FRANKLIN JAMESON, DIRECTOR.

The following report, the seventh annual report of the present Director, covers the period from November 1, 1911, to October 31, 1912. The regular staff of the Department has not been changed during the year, but assistance of great value has been rendered by three Research Associates. For brief periods in the early part of the year Prof. Frank H. Hodder, of the Kansas State University, and Prof. Orin G. Libby, of the University of North Dakota, were associated in Washington with the work of the Department relative to the preparation of the proposed atlas of the historical geography of the United States. The former cooperated in the planning of the portion of the work concerning State boundaries, the latter in that concerning the plotting in geographical form of political votes. A third Research Associate, Dr. Charles O. Paullin, was connected with the work of the Department for four months, laboring upon the atlas in conjunction with these gentlemen, and then pursuing alone the elaboration of the political part of the proposed work. A fourth, Prof. Max Farrand, of Yale University, has in October begun a period of assistance in the matter of economic and social geography. Miss Davenport has remained in Europe throughout the year; Mr. Leland, however, returned in November 1911. The Director and the secretary, Miss Pierce, were in Europe throughout the summer.

In June the quarters which the Department had for eight years occupied in the Bond Building, but which recent building operations in the neighborhood had made unsuitable, were abandoned and others, much more satisfactory, were secured and entered upon. These consist of a suite of nine rooms on the eleventh floor of the Woodward Building, at the southeast corner of H and Fifteenth Streets. The address is 1140 Woodward Building. In certain respects a separate building near the Library of Congress would be more advantageous for the work of the Department than this new suite of rooms; but experience will show whether the nature of our work during the next few years will or will not require so much recourse to the Library of Congress that these advantages of propinquity would overbalance the merits which the present rooms, excellent in themselves, have by reason of their nearness to the business portions of the city.

From the latter part of June until the latter part of September the office work of the Department, mainly in the charge of Mr. Leland during the Director's absence, was carried on in Cambridge, Massachusetts, where by the courtesy of the president of Harvard University and the head of the Semitic Department, an adequate room in the Semitic Museum was placed at the disposal of the Department.

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*Address Woodward Building, Washington, D. C. Grant No. 745. $26,600 for investigations and maintenance during 1912. (For previous reports see Year Books 3–10.)

For statements respecting the general plans of the Department and the purposes which its operations are intended to subserve, the Director begs leave to refer to former reports, and confines the present report to statements respecting the progress of specific publications and other undertakings. The publications of the Department, as has been explained in previous reports, fall naturally into two classes, the one that of reports, aids, and guides, the other that of textual publications of documents. Under these two heads, and a third, relating to the miscellaneous activities of the Department, the work of the past year, and the plans for 1913, will be successively considered in this report.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

Only one volume has been published by the Department during the year. Prof. Marion D. Learned's "Guide to the materials relating to American history in the German state archives," No. 150 of the publications of the Carnegie Institution of Washington, was issued from the press in March as a volume of 352 pages, the contents of which have been sufficiently described in previous reports. The work has received favorable notice in important historical reviews and has already been put to good use by several historical investigators.

Prof. Herbert E. Bolton's "Guide to the materials for United States history in Mexican archives," Publication No. 163, has during the year proceeded toward publication. Although recent disturbances in Mexico are reported to have produced some disarrangement of the established order of the materials in certain archives in the federal city, and may have entailed larger disasters in certain provincial capitals in the north of Mexico, it is hoped nevertheless that Professor Bolton's book may prove to be what it was unquestionably well adapted to be, a permanent help to all investigators in Southwestern history and to the history of our relations with Mexico. Its index is now being made.

The manuscript of the first volume of the "Guide to the materials for American history, to 1783, in the Public Record Office of Great Britain," Publication No. 90A, prepared by Prof. Charles M. Andrews, of Yale University, was dispatched from the office of this Department in the latter part of December. This volume embraces the compiler's general introduction upon the Public Record Office, and an elaborate survey of the American material for the Colonial and Revolutionary periods, contained in what are technically called the State Papers (State Papers Foreign and Foreign Office Papers; State Papers Domestic and Home Office Papers; State Papers Miscellaneous; and Colonial Office Papers). The second volume presents Professor Andrews's detailed account of what are technically called Departmental Records (Admiralty, Audit Office, Custom-House, Treasury, War Office, etc.) and of the miscellaneous section, which embraces the High Court of Ad-

miralty and various expired commissions and special collections. The two volumes are the product of several years of labor on the part of the author. The delays which have been caused by the reclassification to which large sections of the Public Record Office were subjected after the completion of the original plan of the work had their obvious disadvantages, but have enabled Professor Andrews, in the course of the revisions thus imposed, to secure an added degree of perfection in the composition of the book. The reclassifications spoken of having now been brought to an end, so far as they affect any important portions of his work, he has this year, by spending the summer months in London, finished the manuscript of the second volume. The first is now printed and within a few weeks of publication.

This volume, and the other Public Record Office volume already spoken of, and the "Guide to the manuscript materials for the history of the United States to 1783, in the British Museum, in minor London libraries, and in the libraries of Oxford and Cambridge," by Professor Andrews and Miss Frances G. Davenport, Publication No. 90, issued in 1908, complete the survey originally planned of London materials, in public depositories, for our Colonial and Revolutionary history. For the period subsequent to 1783 provision was originally made by the researches of Dr. Charles O. Paullin and Prof. Frederic L. Paxson, conducted in London in 1910. These embraced, at the Public Record Office, the Admiralty papers, Colonial Office papers, Foreign Office papers, and War Office and other papers for the period from 1783 to 1837 (to 1850 in the case of the War Office papers), the papers of the Privy Council Office for the same period, those of the House of Lords from 1783 to 1860, and such material in the British Museum as was not included in the volume prepared by Professor Andrews and Miss Davenport. Later permission to carry the examination of the Colonial Office papers down from 1837 to 1860 was granted, and this work was carried through by Dr. Paullin.

It remained to carry down to the same advanced period (1860) the examination of the Foreign Office and Admiralty papers and those of the Privy Council, in respect to which the desired extension of date had been ultimately accorded. At the time when the last report of the Department was concluded a portion of this work, in respect to the Foreign Office papers, had been performed by Prof. Charles E. Fryer, of McGill University, and Mr. David W. Parker had begun its continuation from the point at which Professor Fryer had been compelled to leave it. During November and December Mr. Parker completed the work, upon the same scale and in the same manner in which it had been conducted by those who had preceded him. Inequalities and differences were inevitable in a manuscript prepared thus by four different hands; but on the whole their extent was less than might have been expected, and before the end of May the finished manuscript was despatched from this office.

The only other archive-guide which the Department has now in the press is Mr. Parker's "Guide to the materials for United States history in Cana-

dian archives," Publication No. 172. A year ago Mr. Parker was reported as having completed his description of the materials for United States history in the archives of the Dominion of Canada at Ottawa, much the largest portion of his book, and his subsidiary accounts of the archives of the provinces of Nova Scotia, New Brunswick, and Ontario. For the archives of the archbishopric of Quebec, the needful report had been prepared by Prof. Frederick J. Zwierlein, of St. Bernard's Seminary, Rochester, New York. All these portions of the volume were sent to the printer in May. Just before the transmission of the manuscript, however, it was discovered that, for reasons for which Professor Zwierlein was not responsible, his account of the civil archives of the province of Quebec was deficient in respect to highly important portions of that repository. This section of the volume has therefore been reserved for fuller treatment by Mr. Leland, who will presently visit Quebec for the purpose.

Delays have also attended the preparation of reports upon the materials for United States history in the archives of British Columbia and Newfoundland, which, however, are shortly expected from the hands of local experts. Brief reports for the newer provinces of the Northwest have been obtained from authoritative local sources.

Since Mr. Leland's return from Paris the work upon the American materials in the archives of that city has gone forward under the effective charge of M. Abel Doysié. It has consisted in the completion of the section called Archives Historiques and the papers of the Section de l'Artillerie and the Comité du Génie at the Ministry of War; in progress in the series B^1, B^2, and B^7 (Décisions, Ordres et Dépêches, and Pays Étrangers) of the archives of the Ministry of Marine anterior to 1790, now transferred to the Archives Nationales; in progress in series B of the archives of the Ministry of the Colonies, similarly transferred, and in the completion of the Louisiana portion of series C; in the completion of the series Espagne in the archives of the Ministry of Foreign Affairs; in various work at the Archives Nationales and the Bibliothèque Nationale; and, among depositories and collections not public, in the examination of the volumes relating to America in the Missions Étrangères and of the papers of General Turreau.

In Seville Mr. Roscoe R. Hill has continued throughout the year, in the Archives of the Indies, his work of describing and listing the materials for the history of the United States in the section entitled "Papeles procedentes de la Isla de Cuba." The whole task involves the examination of nearly a thousand *legajos* (bundles) of manuscript, averaging about 460 documents to the bundle. The section includes nearly a thousand *legajos* that relate wholly or partly to the United States. Of these, a large number were examined between January and November 1911. During the past twelve months Mr. Hill has personally examined about 500 more, and completed descriptions of them upon a uniform plan, such that, upon the average, each *legajo* will be represented by a half-page of printed description in the book

which it is proposed ultimately to issue. Most of these materials belong either to the West Florida section of the "Papeles" or to that comprising the correspondence of the captains-general of Havana.

Meantime, and in addition, some fifty selected *legajos* have received a more elaborate treatment at the hands of the clerks, usually three in number, employed by Mr. Hill, who have in each such case made full lists of the documents embraced in the bundle. It is not expected that these detailed and voluminous calendars will be immediately printed, but they will be preserved in the offices of the Department and made available to investigators through direct consultation or through inexpensive copies. The Department's special apparatus for the photographing of manuscripts is now at Seville, and Mr. Hill has been using it to good effect in securing full copies of a number of documents selected as of especial historical importance.

Particular recognition should be made of the favors and courtesies shown to Mr. Hill by Señor Don Pedro Torres Lanzas, the chief director of the Archives of the Indies, and of the obliging kindness of the American consul in Seville, Mr. Charles S. Winans. Mr. Hill's vacation was mostly spent in Switzerland, affording opportunity for conference with the Director of the Department in respect to the work thus far done and that with which the remaining months of Mr. Hill's service will be occupied. Another part of Mr. Hill's vacation was spent in Lisbon, where, as at Seville, he gave useful assistance to Miss Davenport in the way of locating and photographing treaties.

It remains to speak of one more, though quite minor, expedition for the search of archives. A volume is some time to be prepared upon the materials for American history in the archives of Switzerland, which means, for the most part, in the archives of the Swiss cantons, since those of the Confederation are of little importance for American purposes. The archives of the German-speaking cantons have a very large importance for the history of the great movement of German migration to America in the seventeenth, eighteenth, and nineteenth centuries, to which German Switzerland contributed an exceptionally large contingent. These archives might logically have been included in Professor Learned's German searches; but the amount of time at his disposal necessarily restricted his work to archives within the German Empire. The archives of the German cantons of Switzerland fall to be treated by a separate expedition, of which more will be said in a later section of this report. Those of the five French-speaking cantons are a distinct matter, and could with entire appropriateness be dealt with independently of what is proposed for the German portion of the republic. Migration to America from the French cantons has always been of slight proportions and the materials in their archives which bear on American history are small in quantity and miscellaneous in character, requiring for their treatment not an expert specialist, like those who have made Germanic-American history their peculiar province, but merely a person having a general knowledge of American history. Accordingly the Director resolved to treat these archives himself, since it seemed requisite for him to go to Europe for other

purposes also, with which this enterprise could be combined. He spent July and part of August in Switzerland, and with the aid of the archivists of the respective cantons and of the secretary of the Department prepared statements respecting these archives and their American materials which can be incorporated with the larger work proposed for the German cantons. Grateful acknowledgments should here be made of the aid rendered and favors accorded by the Swiss Minister in the United States, Dr. Paul Ritter, the American Minister in Bern, Hon. Henry S. Boutell, MM. Paul Martin and Charles Roch, archivist and sub-archivist respectively of the canton of Geneva, Abbé Leo Meyer, cantonal archivist of Valais, M. Octave Oberson, sub-archivist of the canton of Fribourg, M. Charles Millioud, sub-archivist of the canton of Vaud, and MM. Arthur Piaget and Louis Thévenaz, archivist and sub-archivist respectively of the canton of Neuchâtel.

After and aside from the performance of some needful preliminary labors, the work done on the Atlas of the Historical Geography of the United States, from January to May, consisted of two parts, the one relating to the boundary-lines of the States, the other to the plotting of political votes. The former involved, on the part of Professor Hodder and Dr. Paullin, careful study of the more important boundary disputes between States, and of statutes and judicial decisions relating to the matter. The representation of political votes is intended to show, on maps of the United States, first, by counties, and in New England by towns, the party complexion of all the presidential elections, and secondly, by congressional districts, the geographical distribution of the affirmative and negative votes on a selected number, perhaps thirty, of the great questions passed upon by Congress in the period from 1789 to the present time. The former, for accurate delineation, requires careful statutory and cartographical study of the history of county boundaries; the latter, a minute investigation of the boundary lines of congressional districts through more than fourteen successive apportionments, a research presenting far more difficulties than would at first thought be supposed. Beginning in consultation with Professor Libby, Dr. Paullin entered on a long investigation of election returns for the early part of our history, in books, newspapers, and archives, and a compilation of results leading to the preparation of election maps in several States. The search for data regarding congressional districts has also been considerably advanced. It is hoped that blank maps of these may be published in advance of the completed atlas, as there is a considerable use of them in university instruction.

In October, as stated in the opening paragraph of this report, Professor Farrand began a period of assistance upon the atlas. His aid will be given in consultations upon those features of the atlas having to do with the representation of economic and social history, and in planning the sheets relating to these divisions of our historical geography.

In Europe the Director had an opportunity to consult with persons occupied with the manufacture of photo-lithographic maps of high grade, and at the Hague and Leyden to confer with those who have principal charge of

the Dutch historical atlas which is now in process of preparation, and which may be regarded in many respects as a model. These were Prof. P. J. Blok, of the University of Leyden, chairman of the commission called into existence for this purpose, and Mr. (Lieutenant) A. A. Beekman, its executive officer, from whom valuable suggestions were obtained.

TEXTUAL PUBLICATION OF DOCUMENTS.

Though from time to time withdrawn to other portions of the Department's work, Dr. Burnett has been able to spend most of his time during the year upon the projected series entitled "Letters of delegates to the Continental Congress." This time has been spent in the process of annotation of these voluminous texts in respect to their relations with the journals, a process which has now been carried to its end save for one year of the Congress.

Miss Davenport, except for a minimum of needful vacation, has occupied herself continuously with her collection of "European treaties having a bearing on United States history." From November to February she was pursuing her subject in Paris, chiefly engaged with the diplomatic history of relations between France and Holland, Spain, and Portugal, in so far as these relate to American history. Early in May she went to Lisbon, and throughout that month and the first part of June was at work there and in Seville upon papal bulls of the period of discovery and Portuguese and Spanish treaties anterior to 1550. A part of September was spent in the archives of The Hague. The remaining portions of the year, except August and October, were filled with work in London, tending to the perfecting of her series in one and another period, all prior to 1713. In October Miss Davenport is returning to the United States.

The series called "Proceedings and debates of Parliament respecting North America, 1585 to 1783," has during the year advanced in several particulars. The copying, or cutting and mounting, of the relevant entries in the Journals of the House of Commons has been carried out through the periods 1727–1741, 1750–1757, and through nearly the whole of the remaining period subsequent to 1766, as well as nearly through the seventeenth century. Mr. Stock has carried down to 1731 the search for relevant portions of the Lords' Journals. The search for printed texts of debates has been pursued through a great number and variety of miscellaneous volumes. Of manuscript reports and debates two interesting volumes were discovered in the library of the Massachusetts Historical Society, and the American portions have been extracted from them. A special source of Parliamentary debates, and one of great interest, lies in the reports which the French ambassadors in London, chiefly in the eighteenth century, obtained by secret means and transmitted to the court of France. These materials, now preserved in the Archives des Affaires Étrangères at Paris, have been described in an article by M. Paul Mantoux in the "American Historical Review" for January 1907 (vol. XII, pp. 244–269). M. Doysié has completed a search for such portions of these reports as relate to American topics.

Manuscript reports of Parliamentary debates, in the period when there was no official or public reporting, exist in considerable numbers in the British Museum and in other libraries in England. Others, however, still remain in private hands. One object of the Director's visit to Europe this summer was, by personal application based upon previous correspondence, to obtain access to these collections and to examine them for the purposes of the proposed series. It is a pleasure to report that in almost all instances success attended these applications. The dukes of Bedford, Leeds, and Northumberland, Lord Lucas, Mr. J. H. Gurney of Keswick Hall, Capt. E. G. Pretyman, M. P., of Orwell Park, and Queen's College, Oxford, through its provost, Dr. J. R. McGrath, kindly permitted the examination of manuscripts in their possession, from which the American portions were extracted. Other manuscripts were similarly examined in three public repositories, the British Museum, the Bodleian Library, and the library of Cambridge University.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the "American Historical Review" has been carried on in the office of the Department and by its staff. Mr. Leland has continued, from Washington, to supervise in Paris the making of a calendar of the papers in the French archives relating to the history of the Mississippi Valley, doing this for an associated group of American historical societies, in accordance with the plan described in a previous report. M. Doysié and clerical assistants have performed the work involved. This has not been performed at the cost of the Carnegie Institution of Washington, but has been of much value to our proposed guide to the Paris archives, which in the parts covered by the Mississippi calendar can, since the latter is destined to be printed, be made for the most part simply a summary of its more detailed indications. M. Doysié and Mr. Leland have also been of much service in Paris, in similar ways, to the State of Mississippi, Yale University, the University of Illinois, the Library of Congress, and various individual investigators.

At the request of the State of Illinois Mr. Leland devoted a month, on leave from the Department, to a survey of the archives of the State and the preparation of a plan for their concentration and administration, in connection with the plans for new State buildings now under consideration at Springfield. He also gave useful testimony at a hearing before the Senate Committee on Public Buildings and Grounds, upon points connected with the proposal for a suitable national archive building in Washington. The Director has, on his own part, considered it distinctly a duty of his office to promote in all possible ways the erection of such a building as a necessary step toward the proper advancement of historical scholarship in the United States.

As in previous years, searches and copies have been made by the Department, or under its supervision, for organizations such as the Wisconsin State

Historical Society, and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with the usual freedom. The Director has, as a matter of course, done what he could in small miscellaneous ways to further the interests in Washington of the American Historical Association and of American historical scholars, and has endeavored to mediate between them and foreign archives and other remote sources of historical information whenever occasion arose.

PLANS FOR 1913.

REPORTS, AIDS, AND GUIDES.

While experience has taught the value of caution in respect to predicting, there seems to be no reason why the ensuing twelve months should not see the issue (after the first Public Record Office volume, above described as nearly ready for issue): first, of Professor Bolton's "Guide to materials for the history of the United States in Mexican archives;" secondly, of Mr. Parker's "Guide to the materials for United States history in Canadian archives;" thirdly, of Dr. Paullin and Professor Paxson's "Guide to materials for United States history, since 1783, in London archives"; and fourthly, of the second volume of Professor Andrews's "Guide to the manuscript materials for the history of the United States, to 1783, in the Public Record Office."

For the completion of the work in Paris, Mr. Leland will expect to go there in April, to work until November, in conjunction with M. Doysié and the clerical assistants.

Mr. Hill expects that his own work at Seville in the "Papeles procedentes de la Isla de Cuba" will be completed in March, and that of his clerks in April. Upon its completion he will return to the United States, and finish for the press the expected volume describing in numerical order the *legajos* of this section of the Archives of the Indies.

It is proposed that Prof. Albert B. Faust, of Cornell University, having leave of absence from that institution, shall in February proceed to Switzerland to make, after detailed researches in the archives of the sixteen German cantons and those of the Confederation, a book which, under the title "Guide to the materials for American history in Swiss archives," shall embrace not only the results of his researches, but those obtained by the Director's examination of the archives of the French-speaking cantons in the past summer. The German part of the book should, for reasons already explained, form a notable aid to the historical study of the Germanic migration to America. It is planned that the volume shall also include, first, data from the remaining (Italian) canton of Ticino; secondly, the results of a thorough investigation of the archives of Salzburg, in all directions bearing upon the emigration, in 1733 and subsequent years, of Protestants from the archbishopric of Salzburg to Georgia; and thirdly, a report upon the materials for American history in the archives of Vienna.

Guides of this sort for students of American history in the main or central archives of England, France, Spain, Germany, Switzerland, Italy, Canada, and Mexico having thus been provided for, there remain only, of independent countries having important relations with American history, the archives of the Netherlands and Scandinavia to be dealt with by way of similar general survey. Provision for these, in 1914 or 1915, has already been planned, and similar examinations of the archives of Scotland, Ireland, and Russia are contemplated. There will also be need, however, of further exploitation of the Spanish and perhaps some other national archives upon which preliminary volumes have already been issued; of extensive searches of provincial repositories in France and Spain; and of careful searches, in so far as they may be permitted, in certain private archives in England. These, however, are matters for fuller consideration in subsequent years.

It is expected that Dr. Paullin, becoming a regular member of the staff of the Department, will devote most of his time during the first part of the ensuing year to the completion of his researches into the history of county boundaries and those of Congressional districts, and through these studies to the preparation of the political portions of the proposed atlas of the historical geography of the United States. The remainder of his time will be given to the planning, in conjunction with Professor Farrand, Prof. Jesse S. Reeves, of the University of Michigan, and the Director, and so far as may be to the preparation, of other portions of the atlas.

TEXTS.

Dr. Burnett will expend as large a part of his time as is possible upon the "Letters of delegates to the Continental Congress." Miss Davenport will give all her time to the book of treaties.

Besides the continuance of the extracting of materials from parliamentary journals and other printed books, for the volumes of "Proceedings and debates of Parliament respecting North America, 1585–1783," the Director, during a brief visit to England in April, will do what he can to bring toward completion the copying of material upon the debates from manuscript sources in the British Museum and in other places not covered by his work last summer. In particular he will address himself to the problem of the journals of debates in the "Unreported Parliament" of 1768–1774, kept by Henry Cavendish, M. P., in the Egerton MSS., 215–263, a problem which has proved to be singularly intricate and difficult, yet eminently deserving of solution if possible, since Cavendish's reports ought to form an invaluable source for a portion of history otherwise little supplied with documentary evidence.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain in 1913 activities similar to those described before, under this heading, in the report relative to the last twelve months.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

The year just passed marks the beginning of a new epoch in the scientific progress of the Department. The building of the yacht *Anton Dohrn* and the repairs upon the laboratory at Tortugas were completed too late last year to enable us to avail ourselves of the enhanced advantages they afford. This year, however, we have been able to offer facilities for research to 15, instead of the usual 10 investigators.

Our new 70-foot, 100 horsepower, twin-screw yacht, the *Anton Dohrn,* has been tested upon a month's cruising in the Bahamas and proves to be thoroughly seaworthy. Her maximum speed is somewhat more than 10 knots per hour, but under economical management, with both engines running, she makes 9 knots and consumes about 15 gallons of gasoline per hour. Under one engine, however, the speed becomes 7½ knots and gasoline consumption 7½ gallons per hour. The supply of gasolene being 1,300 gallons, enables us to run 87 hours under both engines, or 173 hours under one engine. Thus in calm weather we may make 780 nautical miles under both engines or 1,300 miles under one engine. Of exceptionally strong construction, provided with two water-tight bulkheads and a practically flush deck, the yacht may be expected to survive the most severe storms out at sea.

Thus the whole West Indian-Florida region has been opened to our exploration, and it is proposed that we extend the field of our activities and commence a series of biological oceanographic researches embracing the interesting region of the Caribbean Sea and the sources of the Gulf Stream.

The recent expedition of the *Michel Sars,* under Sir John Murray and Professor Hjort, has shown how much may be accomplished in the study of marine biology through the intelligent and courageous use of a small vessel by experts thoroughly trained to the work. It should be a source of regret to us in America that our country, which during the mid-decade of the nineteenth century under Maury and Bache led all others in the scientific study of the sea, should now have fallen into an insignificant place in such researches. Our country, which fostered the labors of Louis and Alexander Agassiz, and of Pourtalès, Sigsbee, and Tanner, should not now be content to lapse into desuetude respecting this important field of study. Even apart from the high scientific interest in such work, the practical side is not to be neglected. That there may be such a side becomes apparent when we remember that the temperature of the coastal water off Scandinavia in May bears a direct relation to the growth of pine trees along the Norwegian shore during the following year. Probably a fuller knowledge of the physical,

* Situated at Tortugas, Florida. Grant No. 746. $18,000 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 3–10.)

chemical, and biological condition in the sea would enable us to predict the periodic success or failure of many of our fisheries.

But to return to the specific plans of the Department: We must have not only an ocean-going vessel such as our *Anton Dohrn* for this work, but a well-equipped land station is almost equally important. The use of complex and delicate apparatus and the maintaining of animals and plants for long periods in a living state are all but impossible upon a ship, but even a small laboratory may provide ample facilities for such intensive studies. Our present bases at Tortugas and at Miami afford excellent opportunities for the study of the Florida Stream, the Yucatan Channel and the adjacent waters of the Gulf of Mexico, and the Bahama Banks, but for the Caribbean it will be desirable in the near future to establish a small branch station in Jamaica.

THE JAMAICA EXPEDITION.

Several of the researches conducted during the past four years at Tortugas led to the conclusion that they should be supplemented by studies carried out in the late winter and early spring months, when, owing to the rough weather, the Tortugas Laboratory can not conveniently be maintained open. Accordingly, in February and March 1912, the Director, accompanied by Professors Louis R. Cary, Hubert Lyman Clark, Joseph A. Cushman, Gilman A. Drew, Robert Tracy Jackson, H. E. Jordan, E. E. Reinke, David H. Tennent, with Mr. George M. Gray as collector, visited Montego Bay, Jamaica. Two houses, belonging to Dr. A. G. McCatty, were rented and served very well for laboratory accommodations; and local boats and men were employed to aid Mr. Gray in collecting for the investigators.

The expedition developed the fact that the region of Montego Bay, Jamaica, is one of the richest in the West Indies in echinoderms, for Prof. H. L. Clark collected 57 species in the shallow waters along the shores of the bay. Many of these forms were extraordinarily abundant, so much so, indeed, that from the laboratory standpoint none of us had seen a better locality for their study. We were fortunate, therefore, in having with us Professor Tennent, whose previous work upon echinoderm hybridization, which he conducted at Tortugas, has attracted so much discussion. At Montego Bay he obtained essentially the same results from the reciprocal cross between *Toxopneustes* and *Hipponoë* (*Tripneustes*) as he observed in Florida, thus proving that the alteration in dominance correlated with the relative acidity or alkalinity (HO ions) of the sea-water is not peculiar to Florida waters. Moreover, he succeeded in effecting an interesting cross between *Toxopneustes* and *Cidaris*. The great care taken in his technique and the constant maintenance of control experiments have ruled out the possibility that his results are due to careless or unclean methods.

Professor Jackson having but just published his monumental work upon the "Phylogeny of the Echini," which marks an epoch in the world's knowledge of the ancestry of these forms, was in a position to avail himself fully

of the opportunity for further study afforded by the varied echinoderm fauna of Montego Bay, and he made a large collection of such species as *Centrechinus* (*Diadema*), *Toxopneustes* (*Lytechinus*), *Hipponoë*, and *Cidaris* in order that he may study their variations. In relation to Tennent's work, it is interesting to state that Professor Jackson found living adult echini upon the Montego Bay reefs which appear to be hybrids between the common species *Hipponoë* and *Toxopneustes*. This leads us to hope that, given suitable conditions, it may be possible for Professor Tennent to rear his hybrids to maturity.

Among other studies carried on at Montego Bay, mention should be made of those of Dr. Joseph A. Cushman, who investigated the living Foraminifera of the shallow waters, and also the fossil forms of the elevated limestones of Jamaica. His studies indicate that a series of dredgings should be carried out in order to determine the bathymetrical range of the several living species, and thus possibly determine the depths beneath the sea from which the limestones of Jamaica have been raised.

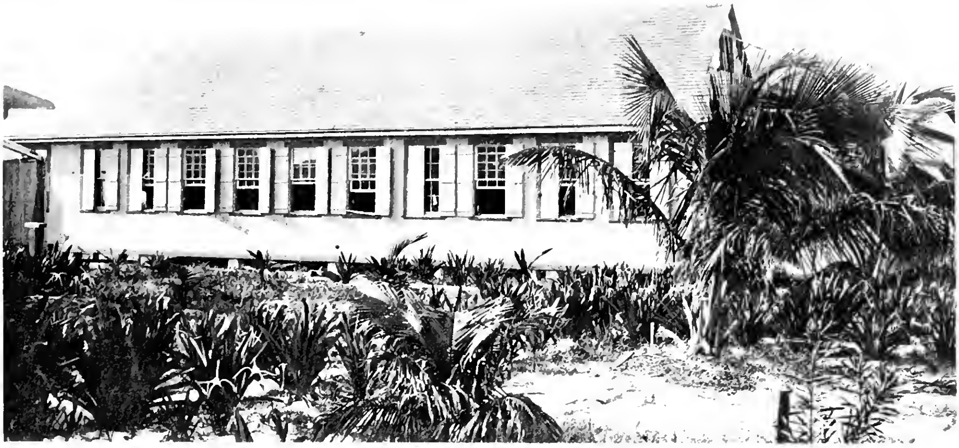
Prof. Gilman A. Drew continued his well-known studies of the spermatophores of cephalopods which he has been conducting for some years past at Woods Hole. Abundant *Octopus* material was obtained from the fishermen at Montego Bay, and indeed the local fishermen were of great aid to us in bringing in many specimens which we ourselves would have found it difficult to obtain.

Prof. H. E. Jordan found that it was impossible to study the maturation and early developmental stages of the eggs of *Echinaster crassispina*, for these star-fishes were not yet ripe, and he therefore investigated the spermatogenesis of the mongoose. Mr. E. E. Reinke acted as general assistant in the management of the laboratory and continued his interesting work upon the two sorts of sperm-cells found in many marine mollusks.

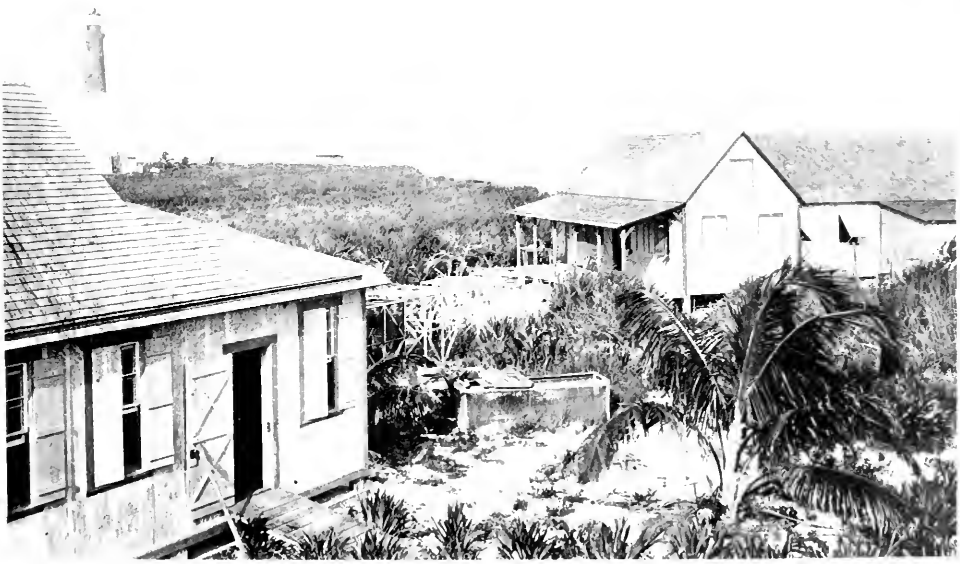
Finally, I can not close this brief account of our work at Montego Bay without alluding to the extraordinary efficiency and energy in our interest displayed by Mr. George M. Gray, curator of the Woods Hole Laboratory, who accompanied the expedition as collector. Mr. Gray is a veteran in this field and he fully succeeded, due to his untiring zeal and to his intimate knowledge of the habits and haunts of marine animals, in providing each and every one of us with all the material we required.

To His Excellency the Right Honorable James Bryce, British Ambassador to America, we are indebted for letters to their excellencies the governors of Jamaica and of the Bahamas. In response to these credentials, His Excellency Sir Sydney Olivier, K. C. M. G., governor of Jamaica, was so kind as to permit us to import our scientific apparatus free of customs duties, and he displayed toward us other appreciated acts of courtesy, in these being joined by the Honorable W. Coke Kerr, esq., Custos of St. James.

To Henry M. Doubleday, esq., American consul at Montego Bay, and to Mrs. Doubleday, it is a pleasure to express our appreciation of their cordial



The new Laboratory Building in July, 1912.



The new Machine Shop at Tortugas, July, 1912.

welcome and invaluable advice upon the intricate subject of maintaining a household in Jamaica. Altogether our many kind friends united to produce upon us a charmed impression of this most beautiful of tropical islands in the western hemisphere.

It is remarkable that in many respects, from a biological point of view, the region of Montego Bay supplements that of the Tortugas. For example, at Tortugas one finds great areas of shallow flats, whereas a depth of 2,000 fathoms is met with 5 miles off shore at Montego Bay. The richest coral reefs of Florida are at Tortugas, whereas at Montego Bay there are only isolated reef patches of small area. The animals of Tortugas are exclusively those of a limestone region devoid of mud, whereas at Montego Bay there are many creatures living in the mud flats. Thus at Tortugas the fish and coral faunæ are superior, while at Montego Bay there are more echinoderms, actinians, mollusca, and worms. On the whole, were the Tortugas Laboratory to be supplemented by a small branch station at Montego Bay which could be open from January until April during the months when the unprotected character of the Tortugas reefs render them inaccessible to the collector, we would then be able to direct our efforts to the successful study of nearly every biological problem of the West Indian region. Moreover, the deep sea to the northward of Jamaica may be expected to yield important results in the fields of oceanography and biology, supplemented as such studies would be by work within the region of the immediate sources of the Gulf Stream in the Yucatan Channel and off the Tortugas and the Bahama Banks.

THE BAHAMA EXPEDITION.

The Director, together with Doctors Paul Bartsch, G. Harold Drew, and T. Wayland Vaughan, spent the month of May upon an expedition to the Bahamas, during which time we cruised 570 miles in the yacht *Anton Dohrn*.

In cruising from Miami, Florida, to Golding Cay, Andros Island, we visited Nassau en route in order properly to enter the group, and especially to enjoy the privilege of presenting the letter which the British Ambassador, the Right Honorable James Bryce, had addressed in our behalf to the governor of the Bahamas.

As in Jamaica, so in the Bahamas, we were received with every courtesy, and His Excellency Sir William Grey-Wilson, K. C. M. G., the governor in council, was so kind as to authorize the receiver general to permit us to import dredges to be used in our scientific work in deep water.

To the Honorable W. Hart-Bennet, esq., the colonial secretary, to the late Sir James Young, Kt., and to Lenox E. Forsyth, esq., commissioner of Andros Island, it is a pleasure to express our sense of gratitude for many thoughtful and kindly acts which rendered our visit to the Bahamas both scientifically profitable and socially delightful.

A word may be said respecting our reasons for visiting Golding Cay, Andros Island: For the past five years Dr. T. Wayland Vaughan has been

engaged upon the intensive study of the reef corals of Florida, and in order to render his conclusions of wide import, it seemed desirable that he should visit the richest barrier reef of the Atlantic—that lying along the eastern coast of Andros Island from the South Bight to Morgan's Bluff.

Moreover, the work of G. Harold Drew, esq., of Cambridge University, had demonstrated that off Port Royal, Jamaica, and at Tortugas, Florida, a bacillus which is abundant in the surface-waters of the tropical sea denitrifies the nitrates and nitrites, giving off free nitrogen, probably in the manner observed by Bauer and by Brandt. Drew also found that the activity of this bacillus caused precipitation of calcium carbonate in the warm surface layers of the ocean to a far greater degree than one would have been led to suspect from the researches of Forchhammer, and of Murray and Irvine, who observed the precipitation of calcium carbonate with liberation of ammonia. Shells and corals are probably formed in this manner, but these authors appear to have overlooked the importance of the precipitation of calcium carbonate in some such manner by bacterial action, yet Drew discovered that the vast submarine limestone deposits of the Florida-Bahama region, which have hitherto been called "coral muds," are not chiefly composed of shells, corals, echinoderms, or the skeletons of nullipore algæ, but of finely-divided particles of limestone which have been precipitated through the agency of marine bacteria. It became important, therefore, for him to extend these studies to the quiet waters of the deep Tongue of the Ocean off Andros Island, where the currents might not be strong enough to cause anything like the ascending and descending masses of cold or warm waters observed in the Gulf Stream region. Thus in this deep and presumably stagnant water he hoped to determine the bathymetrical distribution of this bacillus, and his studies in this respect were altogether successful.

The *Anton Dohrn* was equipped with a self-closing Nansen-Bigelow net with which the Director hoped to gain an idea of the bathymetrical distribution of the surface, intermediate, and bottom fauna of the deep water of the Tongue of the Ocean, but owing to the prolonged rough weather and the necessity that Mr. Drew's research should take precedence over other matters, but little could be done except to discover that the region is a rich one for deep-sea pteropods, crustacea, siphonophores, and medusæ. A special expedition will be undertaken to attempt the serious study of this region, for one would expect this deep water to be less disturbed by currents and eddies than are most parts of the Florida-Bahama region in the neighborhood of the Gulf Stream.

Dr. Paul Bartsch accompanied the expedition to assist Dr. Vaughan in collecting corals and also to study the mollusca, in the knowledge of which group he is an expert. He collected many thousands of *Cerion* of various races or species, each islet of the Andros group seemingly having its own peculiar variety of this common land-snail. In order to test the effect of local conditions, isolation, etc., several thousand living *Cerion* from Andros

Island were taken to Florida and colonies were planted on the Ragged Keys, Indian Key, The Tea-Table, Newfound Harbor Keys, Duck Key, Bahia Honda, Boca Grande, and Tortugas, Florida. The results of these experiments will be awaited with interest, for so plastic an organism as *Cerion* may be expected to vary appreciably in a few generations when subjected to such widely changing environmental conditions, and light may thus be thrown upon the nature of the causes that produce the extraordinary variability in other mollusca such as the Partulæ and Achitinellidæ of the Pacific.

An important discovery made upon the expedition was that of Dr. T. Wayland Vaughan, who agrees with Shattuck and Miller in that the Bahamas for a few feet above tide-level are composed of limestones of submarine origin which have been elevated to form a base upon which the superimposed æolian limestones have been formed. Vaughan, however, made the additional discovery that this elevated limestone of submarine origin is identical with the Miami oölite of Florida. But the intensive examination of the limestones of the Bahamas and of the Florida Keys which we visited in returning led him to an even more interesting conclusion. Drew's bacillus, as we have just stated, causes a constant precipitation of calcium carbonate in the warm surface layers of the tropical ocean. This flocculent matter settles loosely upon the bottom, and, as Vaughan observed, the mud thus formed soon becomes filled with minute bubbles of gases due to the decomposition of the animal and vegetable matter contained within it. These bubbles form either separately or around solid particles. As soon as the bubbles are formed, finely divided particles of limestone are attracted and settle upon their surface films. It is possible that some of the Florida-Bahama oölite is formed in some such manner, but Dr. Vaughan has observed that if finely divided limestone mud be maintained under water in bottles oölites may form independently of bubbles.

This work of Vaughan upon the oölite was rendered possible through the generous gift by the Hon. John B. Henderson, Regent of the Smithsonian Institution, of an excellent dory launch, which we have seen fit to name the *Henderson*. This launch is 23 feet long and has a 6-horsepower engine capable of driving her at the rate of 9 miles per hour. The draft is so light that we were able to travel for miles over the shallow flats of Florida in places inaccessible to our other boats.

One object in seeking Golding Cay Harbor, Andros Island, as our base was that the Great South Bight, which opens to the eastward at this place, permitted us to pass through the island in our launch *Velella* and to study the remarkable "white marl" of its western coast.

While at Golding Cay, Dr. Vaughan made a collection of the more interesting reef corals, and he also measured 135 specimens and cemented them upon tiles, and then affixed them to iron stakes which were driven into the reef in favorable places for observing the growth-rate; for we expect to return to Golding Cay in 1914.

The harbor of Golding Cay, Andros Island, is one of the best along the formidable barrier reef of the eastern side of the island. No detailed chart of it has, however, been published, and believing that so important a place of refuge should be more accessible, the Director made a compass survey of the harbor, which is published herewith, and is believed to be sufficiently accurate for purposes of ordinary navigation (Plate 3). Vessels drawing 9 feet may enter at high tide, and the recommended anchorage is in good holding ground on a muddy bottom.

STUDIES AT TORTUGAS.

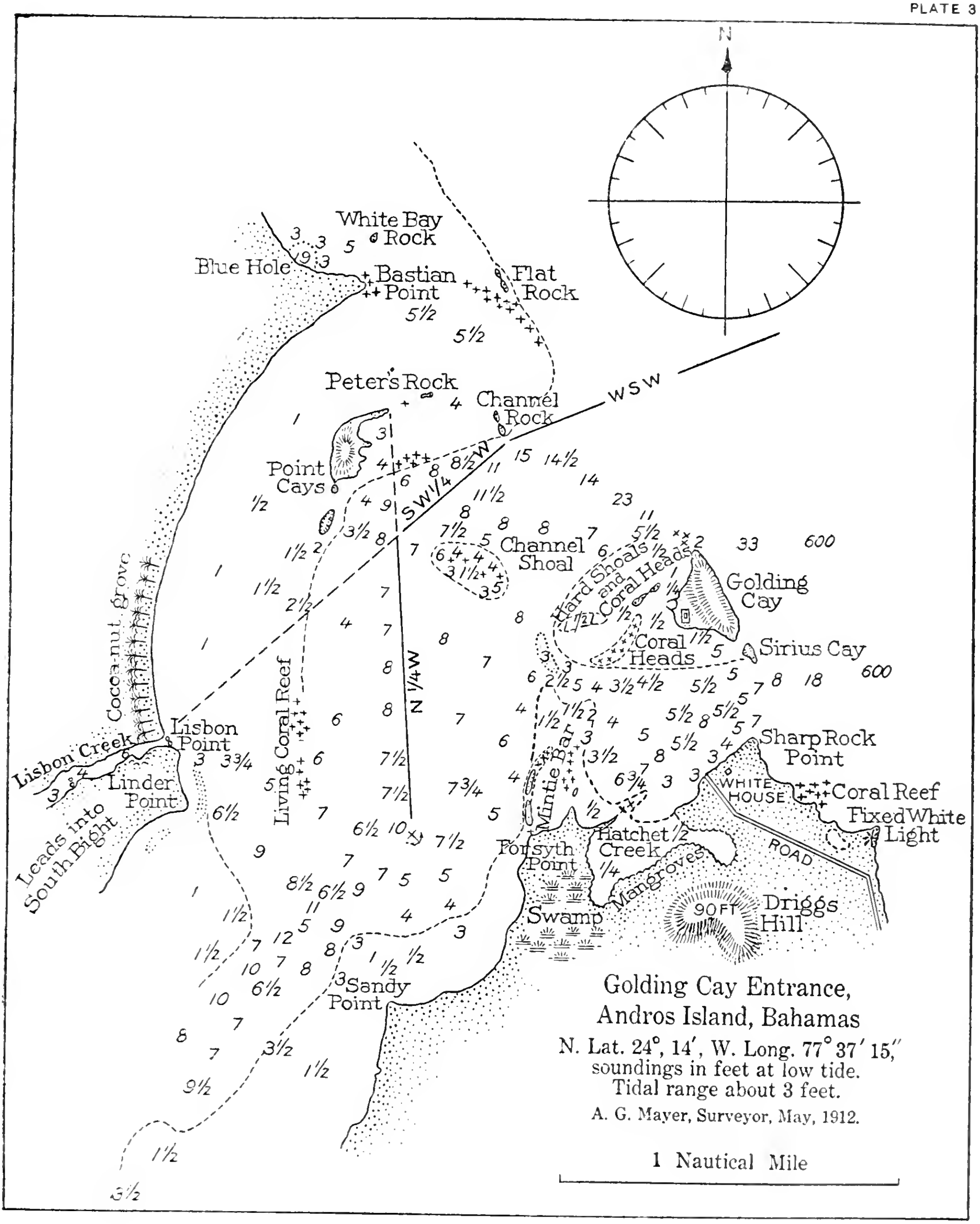
During June and July the Director, accompanied by Professors L. R. Cary, A. J. Goldfarb, E. W. Gudger, T. Wayland Vaughan, and John B. Watson, remained at Tortugas, where we installed the new hard-rubber pump and pipes designed to supply our aquarium tanks with constantly running sea-water. This hard-rubber circuit proves to be entirely satisfactory, and the most delicate marine animals appear to thrive in our tanks. The large glass supply-tank into which the water is pumped is maintained in darkness to prevent the growth and subsequent decomposition of plant life within it, and all pipes are impervious to light. A trestle-work about 60 feet long extends from the eastern shore of the island and carries the intake pipe out to pure water.

Dr. L. R. Cary, who studied at Tortugas from August 15 to September 5, continued his observation upon the growth-rate and regeneration of gorgonians. He concludes that the breeding season in these forms is of brief duration. During the first year *Gorgonia flabellum* becomes somewhat less than 50 mm. high. At the end of the second year it is about 150 mm., at the end of the third year 220 mm., of the fourth 280 mm. in height, after which it continues to grow slowly until it becomes about 750 mm. high. Thus, in common with the stony corals, the relative growth-rate is greater during the second year than at any other time.

Professor Goldfarb found that if larvæ of certain echini, such as *Centrechinus* (*Diadema*), *Hipponoë,* and *Lytechinus* (*Toxopneustes*) were subjected to solutions of magnesium or of sodium salts and then returned to sea-water, the entoderm evaginates in the manner discovered by Herbst, who, however, used lithium chloride to produce this result.

Professor Goldfarb also found that if the eggs be subjected to the action of sea-water containing an excess of sodium chloride and then removed to natural sea-water, some of them fuse or adhere to one another, producing double or giant embryos, or causing the fusion of many eggs into masses which develop in an abortive manner.

In another series of experiments, Professor Goldfarb cleverly drew out the ventral nerve-chain of the annelid *Amphinoma,* and found that these worms regenerate in a normal manner, and therefore regeneration is not initiated by stimuli from the axial nervous system.


N
White Bay Rock
Blue Hole
Bastian Point
Flat Rock
Peter's Rock
Channel Rock
WSW
Point Cays
SW 1/4 W
Channel Shoal
Hard Shoals and Coral Heads
Golding Cay
Coral Heads
Sirius Cay
Cocoa-nut grove
Lisbon Creek
Lisbon Point
Linder Point
Leads into South Bight
Living Coral Reef
N 1/4 W
Mintie Bar
Sharp Rock Point
WHITE HOUSE
Coral Reef
Fixed White Light
Forsyth Point
Hatchet Creek
Mangroves
ROAD
Swamp
90 FT
Driggs Hill
Sandy Point
Golding Cay Entrance,
Andros Island, Bahamas
N. Lat. 24°, 14′, W. Long. 77° 37′ 15,″
soundings in feet at low tide.
Tidal range about 3 feet.
A. G. Mayer, Surveyor, May, 1912.
1 Nautical Mile

He also found that various marine animals are much more sensitive to concentrated than to diluted sea-water, and in this research he made a series of observations upon the regeneration of *Cassiopea* in diluted, normal, and concentrated sea-water, the concentration being accomplished by partially evaporating the normal sea-water. He found that regeneration is more rapid in slightly diluted than in normal sea-water.

Prof. E. W. Gudger studied the anatomy and breeding habits of several species of sharks and rays, paying special attention to the nurse shark. He also made general observations upon the habits of the reef fishes, and it is hoped that the laboratory may be able to afford him every possible facility in this work, for but little is known of the breeding habits of the coral-reef fishes, and Professor Gudger's success in the study of many hitherto undetermined or obscurely known habits of fishes leads us to hope that he will make some equally important discoveries at Tortugas.

Dr. T. Wayland Vaughan found that the reef corals feed upon the animal plankton, but not upon the plant life of the ocean. He found that corals require to be fed more constantly and more copiously than had hitherto been supposed, and that we can readily distinguish a well-fed from an underfed coral by its appearance. He also tested the effects of exposure to air and found that reef corals are remarkably tenacious of life when dried, thus accounting for the fact that the living reefs withstand exposure over wide areas at the low tide of the spring tides. Dr. Vaughan also remeasured and photographed his many specimens of corals that are growing in various situations, and which are expected to furnish an idea of the average rate of growth of corals upon the reefs.

Prof. John B. Watson expected to determine the limits of the visible spectrum for the noddy and sooty terns of Bird Key. This may possibly have some bearing upon the actuating cause of the migratory or homing instincts in these sea-birds. Accordingly, he brought a heliostat and spectroscope with him from the Johns Hopkins University, and with his own hands made an excellent dark-room in which to perform the experiments, in the meantime rearing the young birds with all possible care. It was found, however, that the gasoline engine at Tortugas could not generate a non-flickering electric light, and Professor Watson therefore took the young birds to Baltimore, hoping to study them under the best possible conditions of stimulation in his laboratory. Unfortunately, however, they died one after another before he could obtain decisive results, and the experiment must be tried over again. It is hoped that with improved facilities this experiment may be conducted at Tortugas next year. The great care and labor involved in rearing the young gulls renders it doubly regretful that Professor Watson's well-planned experiments were doomed to end in a temporary disappointment.

Alfred G. Mayer took many kymograph records designed to illustrate the behavior of the pulsating *Cassiopea* when subjected to varying concentrations of the several cations of sea-water and to differing temperatures, the

object being to throw light on a possible relation between the degree of ionization and reaction. These curves are remarkably regular and show that the rate of transmission of the nervous impulse which produces pulsation varies as does the degree of dissociation of the ions of the sea-water above or below the normal. For stimulating cations this ratio is direct, but for inhibiting cations such as Mg it is inverse. In another research the Director determined the temperature limits of various marine animals, especially the reef corals. The reef corals can not long withstand intense heat, a water temperature of 99° F. being fatal to most of the species. *Siderastrea radians* is most resistant to temperature changes, its life-limits ranging from about 42° to 101° F.; and one specimen survived with some maceration after being 11 hours in the ice-box, the final temperature of the water surrounding it being 35.4° F. It is difficult to see why this coral does not range much farther north than the other reef corals. The most sensitive of the reef-building forms appears to be *Orbicella annularis,* whose life-limits are between 58° and 97.5° F.

We have record of a northerly storm in the winter of 1911–12 which cooled the water in the moat at Fort Jefferson to 63° F. In view of this, I maintained various reef-corals at a water-temperature of as nearly as possible 57° F. for 9 hours, and then returned them to the ocean, which was at its normal summer temperature of about 82.5° F. As a result of these experiments I am led to conclude that were the sea-water surrounding the corals to be cooled to 57° for 9 hours *Siderastrea radians, S. siderea,* and *Mœandra areolata* would survive without apparent injury, while *Porites furcata, Mœandra clivosa, Porites clavaria,* and *Favia fragum* would probably survive with more or less maceration of tissue, the first named being the hardiest. On the other hand, *Orbicella annularis, Porites astreoides,* and *Acropora* (*Madrepora*) *cervicornis* would be killed. In general, the shallower and the more stagnant the water in which the coral normally lives, the more able it is to withstand high or low temperatures.

Relatively deep water forms, such as *Eusmilia knorri* and *Oculina diffusa,* are not so resistant to heat as the reef-builders, being killed at 97° F.; but on the other hand they withstand cold quite as well if not better than most of the shallow-water forms.

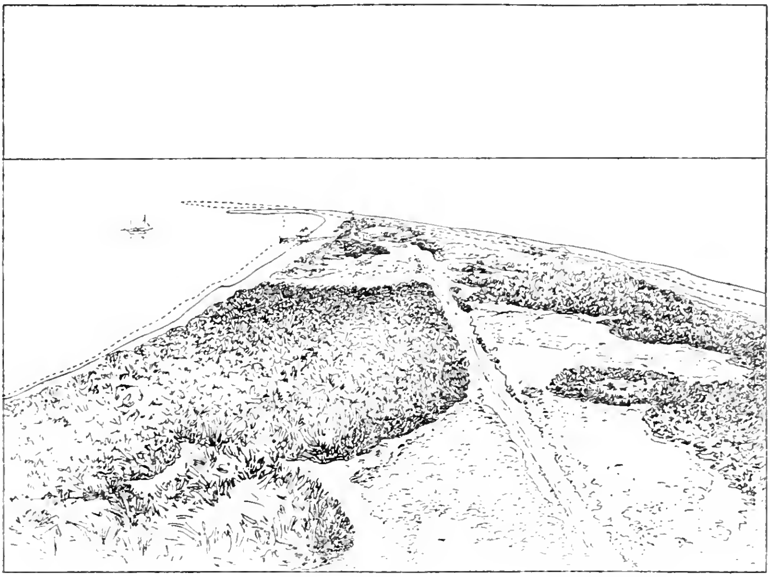
In common with other tropical marine creatures, the corals live in an environment which is much closer to their death temperatures than that of northern animals. One may contrast the behavior of the most resistant coral, *Siderastrea radians,* which can survive between 101° and 42° F. and which lives in water ranging between 92° and 63° F., with some such form as *Limulus,* which ranges from Maine to Yucatan and survives between 110° and — 2.75°, being able to withstand being frozen into the ice.

In another research the Director continued the study of the rate of starvation of *Cassiopea xamachana* in sea-water sterilized in various ways, the animals being either normal or regenerating, or in light or in darkness. It

is hoped that this research may eventually throw some light upon the possible efficacy of sea-water or of some of its normally present organic or inorganic constituents in serving as a source of food for marine animals. It will, however, be necessary to devote several months to a detailed study of the results of the experiments before conclusions should be drawn.

In addition to the studies mentioned above, Prof. Ulric Dahlgren, of Princeton University, was enabled to visit Norfolk, Virginia, to continue his studies upon the development and histology of the electrical organs in *Asteroscopus*.

As a consequence of readjustments following the hurricane of October 17, 1910, the sandy shore of Loggerhead Key has moved westward and north-



EFFECTS OF HURRICANE OF OCTOBER 17, 1910, AT LOGGERHEAD KEY.

Looking northward from top of light-house. Full line shows shore-line as it was in July 1905; dotted line shows shore as it was in July 1912.

ward, and the end of our laboratory dock on the western side of the island, which in 1905 projected at least 34 feet beyond the shore line, is now 5 feet inward from the edge of the water at low tide. There is now less than 2 feet of water near the end of our dock in a place where, according to Dr. Vaughan's measurements, there was a depth of 8 feet in 1911. The laboratory buildings, which in 1909 were nearer the western than the eastern side of the island, have now become reversed in this relation, the island as a whole having gone to the westward. It may prove to be necessary in 1913 to extend our western dock and to build new dock-houses. The outline drawing published herewith has been traced from two photographs, each taken from the same site at the top of the lighthouse, the first in July 1905

and the second in July 1912. The shore-line as it was in 1905 is drawn in full, while that of 1912 is dotted. Our buildings, which once occupied the center of the island, are now quite close to the eastern shore.

A list of the names of the investigators and of the places wherein they studied is herewith presented:

Name.	Place of study.	Time devoted to study.
Dr. Paul Bartsch, U. S. National Museum, Washington.	Bahamas, Florida	Apr. 28 to June 6.
Dr. L. R. Cary, Princeton University	Jamaica, Tortugas	Feb. 22 to Mar. 22. Aug. 15 to Sept. 5.
Dr. Hubert Lyman Clark, Harvard University Museum.	Jamaica	Feb. 22 to Mar. 22.
Dr. Joseph A. Cushman, Boston Society of Natural History.	Do.	Do.
Prof. Ulric Dahlgren, Princeton University	Hampton Roads, Va.	August.
Prof. Gilman A. Drew, Resident Assistant Director of Marine Biological Laboratory at Woods Hole.	Jamaica	Feb. 22 to Mar. 22.
G. Harold Drew, esq., B. A., Cambridge University, England.	Bahamas	Apr. 18 to June 1.
Dr. A. J. Goldfarb, College of the City of New York	Tortugas	June 11 to July 25.
Mr. George M. Gray, Curator of Woods Hole Laboratory, Collector.	Jamaica	Feb. 22 to Mar. 22.
Prof. E. W. Gudger, North Carolina State Normal College.	Tortugas	June 6 to July 25.
Prof. Robert Tracy Jackson, Boston Society of Natural History.	Jamaica	Feb. 22 to Mar. 22.
Prof. H. E. Jordan, University of Virginia	Do.	Do.
E. E. Reinke, esq., Princeton University	Do.	Do.
Prof. David H. Tennent, Bryn Mawr College	Do.	Do.
Dr. T. Wayland Vaughan, U. S. Geological Survey	Bahamas, Tortugas	Apr. 28 to July 25.
Prof. John B. Watson, Research Associate	Tortugas	June 6 to July 12.

In response to certain inquiries, it may not be inappropriate to speak of the general aims and mode of management of the Department of Marine Biology. In common with other projects maintained by the Carnegie Institution of Washington, it is our purpose to endeavor to assist investigators whose previous work has demonstrated their ability to succeed in research. We hope to place before them the best facilities for the advancement of their investigations, maintaining above all that freedom of thought and action so essential to the spirit of research. Toward all other educational institutions it is our duty to serve as an aid, supplementing but never rivaling their efforts. Indeed, we may well avoid fields in which the harvest is being reaped, for our place should be in domains hitherto inaccessible or neglected. We must not duplicate but originate investigations.

It is true that, the field of research being so vast, we must neglect more than we can ever hope even to attempt; and this policy of definitely planned investigations has led to an all too evident narrowness of scope in the work the Department has performed, yet it is above all our aim to achieve thoroughness in a few things rather than superficiality in many, believing that science of to-day is being advanced by intensive studies rather than by broad surveys.

The following five researches have been published during the year as a result of studies conducted at Tortugas, Florida:

G. Harold Drew, Cambridge University, England. The action of some denitrifying bacteria in tropical and temperate seas, and the bacterial precipitation of calcium carbonate in the sea. Journal of the Marine Biological Association, Plymouth, England, vol. 9, pp. 142-155, October 1911.

Alfred G. Mayer, The Carnegie Institution. Ctenophores of the Atlantic coast of North America. Publication No. 162 of the Carnegie Institution of Washington, 58 pp., 17 plates, 12 text-figures, March 1912.
Edith Pinney, Bryn Mawr College. A study of the chromosomes of *Hipponoë esculenta* and *Moira atropos*. Biological Bulletin, Woods Hole, vol. 21, pp. 168–186, 31 figs., August 1911.
H. S. Pratt, Haverford College. On *Galactosomum cochleariforme* Rudolphi. Zool. Anzeiger, Bd. 38, pp. 143–148, 5 figs., August 1911.
D. H. Tennent, Bryn Mawr College. A heterochromosome of male origin in echinoids. Biological Bulletin, Woods Hole, vol. 21, pp. 152–154, 3 figs., August 1911.

Sixteen investigators are now prepared to present the results of their studies, and it is expected that these papers will provide manuscript for at least two more volumes of the series of "Researches from the Tortugas Laboratory," of which volumes 1 to 4 have already been published by the Carnegie Institution of Washington.

In conclusion, it is a pleasure to speak of our appreciation of the kindness of the late Admiral Young, U. S. N., who as Commandant of Key West, did much to aid us in our studies.

REPORTS OF INVESTIGATORS.

Planting Bahama Cerions upon the Florida Keys, by Paul Bartsch, U. S. National Museum.

At the invitation of Doctor Mayer I joined the expedition of the *Anton Dohrn* to the Bahama Islands, the main object of my visit being an ecological study of the marine mollusks of the region, with special reference to the boring and nestling organisms associated with corals. Collections were made wherever possible, but most of the work was done in the region of the east end of South Bight, Andros Island. The marine mollusks proved rather disappointing, there being but few species, and these, with few exceptions, were poorly represented in numbers. A detailed report of the findings will be made in the near future. The land shells of the region proved far more interesting than the marine mollusks, and among these the genus *Cerion* presents some most interesting problems.

Andros Island is a collective term applied to a whole host of minor keys, separated by tortuous channels of varying width and depth. Practically each key examined, no matter how small, provided it bears vegetation, excepting those in the Tongue of the Ocean, which are at times dashed over by ocean waves, is inhabited by *Cerions* of the *glans* group. Sufficient differentiation has taken place on each key to enable one to distinguish the shells from the different keys. For example, in size alone, 500 of those collected about Bastion Point (see map, plate 3) filled a 3-pint measure, while the same number from the neighborhood of our temporary laboratory (the "White House," near Sharp Rock Point) required a 5-pint measure to contain them. There are also other characteristics correlated with size.

On the northwest side of Linder Key, along Lisbon Creek, a series of swales separate an equal number of wooded elevations only a few feet above high-water mark. We found that these swales separate different races of *Cerions*. What has been said of the *glans* group also holds good of the painted *Cerions* wherever they occur, although their distribution seems to be more restricted. In the light of all these puzzling facts, it was deemed de-

sirable to gather large series of specimens of *Cerion* and associated mollusks for careful laboratory study and experimentation, and this was accordingly done.

Of *Cerion* alone about 40,000 specimens were gathered from as many localities as were within our reach. From the two places already mentioned, (1) along Kings Road, Bastion Point, northeast side of South Bight, Andros Island, and (2) in the neighborhood of the laboratory, between Sharp Rock Point and Driggs Hill, on the southeast side of South Bight, especially large series were collected, which were to serve for planting and as a reserve series for comparison with the progeny of the transplanted material.

On our return to the Florida coast, plantings of these two races were made, as follows: May 28, 1912, there were planted 500 of No. 2, on the sandy beach on the middle of the outside of the first of the Ragged Keys, north of Sands Key; 500 of No. 1 were planted on the second of the Ragged Keys, north of Sands Key; also on the sandy beach on the outer shore. The next planting was made on June 1, on Indian Key, where 500 of No. 2 were placed about the old ruins of a house on the bay side of the key. On the same day 500 of No. 1 were planted on the Tea Table Key. These were also scattered about the ruins of the old house on the north side of the island. On June 2 plantings were made on Bahia Honda, where 500 of No. 2 were placed on the northwest side of the deep cut which runs parallel with the outer beach, 500 more of No. 1 were planted on the south side of Duck Key. On June 3 we planted 500 of No. 1 in the middle of New Found Harbor Key.

Being unable to continue to the Tortugas with the party, since the time allotted for my trip had expired, Doctor Mayer kindly made the following plantings for me: June 8, 500 of No. 1 beneath the U. S. Coast Survey beacon, on the northwest end of Boca Grande Key. A planting of 138 of No. 1 was made back of a small unpainted house on the northeast side of the fort, on Garden Key, Tortugas. On Loggerhead Key, Tortugas, three plantings were made, as follows: 500 of No. 2 on the left-hand side of the path (marked by a stake) between the light-house and the laboratory, 600 feet north of the light-house; 500 of No. 1 at the southern end of the island, also marked by a stake, and another planting near the boat-house at the middle of the western shore of the island, consisting of a mixture of 500 each of Nos. 1 and 2. The southern planting is 1,000 feet from the middle, and the northern 800 feet from the middle one. In addition to this, 73 specimens of a small painted *Cerion* were planted on Bird Key and the place was marked by a stake.

All of the planted material, except the specimens left on Boca Grande, were marked by making two fine parallel cuts with a file across the ribs on the back side of the antepenultimate whorl, and all were adult shells. The snails of all colonies planted upon the Tortugas appeared to be thriving well in July 1912, but no young individuals were observed.

During our cruise from Miami to Key West, a special effort was made to examine as many of the keys as we could reach conveniently for *Cerion incanum* Binn., and wherever found to gather as large a series as possible. It was observed that most of the keys which had been flooded during the hurricanes of 1906 and 1910 contained practically no live *Cerions,* though dead ones were observed in a number of places, and this caused one to wonder whether sea-water, as such alone, might serve as a decided barrier to these forms. This also seemed to be indicated by the fact that the living *Cerions* collected were always found beyond the reach of the ocean spray,

far above the hurricane rampart, on the outer keys, which are exposed to severe storms, but much nearer high-tide mark in the sheltered places along the various bights and small channels.

With these points in view, experiments were conducted in Washington upon the two races planted on the Florida Keys. Beginning with an immersion of 30 seconds through intermediate stages up to 5 days, it was found that some of the *Cerions* could withstand an immersion of 4 days in sea-water, but the 5-day experiment seemed to be fatal to them.

These experiments were made by tying the specimens in a piece of bobinet and immersing them in a jar of sea-water, the latter being changed daily in the prolonged experiments.

Little is known about the life-history of *Cerions;* but they are known to be remarkably variable and usually very restricted in their distribution and very abundant where they occur. They are very tenacious of life, for we have had specimens in the U. S. National Museum for more than eight years which occasionally leave the tray in which they are placed and seek a new resting-place. They are also not particular about specific food, in fact, I have come to look upon them as "the goats" among the Mollusca. Then, too, they are not readily affected by changes in temperature, since the U. S. National Museum was not heated on Sundays, and the temperature surrounding those above referred to was quite low on this day during the winter season. All these features point to this group as a remarkably desirable one for investigation, with the hope that the various experiments to which they might be subjected would eventually yield information to enable us to understand what is meant by "the Protean nature" of this group.

Report upon Anthozoa, by L. R. Cary, Princeton University.

The studies upon gorgonians begun at Tortugas in 1910 were continued during the present year. In February and March, while at the temporary laboratory established by Dr. Mayer at Montego Bay, Jamaica, an opportunity was afforded to continue observations under the conditions occurring on the Jamaica coast, which differ to a considerable degree from those prevailing in the neighborhood of Tortugas. Owing to the shortness of the season at Montego Bay, the results were of necessity those of observation rather than of experiment, and will supplement the more extensive work carried on at Tortugas.

The sensitivity of different regions of the body and the general reactions of the hydroid *Amalthæa degeneratus,* which is probably the hydroid of *Pachycordyle degeneratus* Mayer, and which I discovered growing in clusters upon the shaded piers of the United Fruit Company's wharf at Montego Bay, were studied in detail in order to procure a physiological basis with which to correlate the structure and arrangement of the nervous system in this form. Its nervous system was studied by the use of the methylene blue method of intra-vitam staining, and an abundance of material was preserved by the methods of fixation necessary for the use of several of the silver-nitrate and gold-chloride methods of staining nerve-tissues.

OBSERVATIONS UPON GORGONIANS AT TORTUGAS.

The following table gives the results of the measurements of the gorgonians growing attached to a large coral head, *Orbicella annularis,* for which growth records have been kept since June 1910:

Specimen.	Gorgonia flabellum.					Plexaura flexuosa.				
	Original height.			Increase from—		Original height.			Increase from—	
	June 1910.	July 1911.	Aug. 1912.	1910–11.	1911–12.	June 1910.	July 1911.	Aug. 1912.	1910–11.	1911–12.
	mm.	*mm.*	*mm.*	*p. ct.*	*p. ct.*	*mm.*	*mm.*	*mm.*	*p. ct.*	*p. ct.*
No. 1	100	150	gone	50	....	80	135	175	68.77	29.62
2	100	150	155	50	3.33	150	155	210	3.3	35.48
3	70	145	183	107.14	26.20	50	83	101	66.66	21.68
4	300	330	374	10	10.30	245	269	287	9.7	6.69
5	150	219	245	46	12.38	115	163	183	41.39	12.27

While the few observations here recorded show the rate of growth of different individuals to be quite irregular, they nevertheless indicate in a general way that the percentage of increase in size becomes progressively smaller from year to year.

In the following table are presented records for a number of specimens of the same forms which were put upon tiles in July 1911. These results confirm those obtained from the previous observations and are in some instances, because of the smaller sizes of the specimens taken for observation, much more striking than were those previously obtained.

Tile and species.		July 1911.	Aug. 1912.	Increase.
		mm.	*mm.*	*p. ct.*
Tile 1	G. flabellum	65	148	127.69
	P. flexuosa	130	150	15.38
Tile 2	P. flexuosa (a)	145	175	20.62
	P. flexuosa (b)	70	120	71.43
Tile 3.	G. flabellum	41	124	202.43

Upon the surface of the coral head, where are growing specimens recorded in the first table given above, there were found on August 21 of this year, 7 specimens of *P. flexuosa,* which had become attached since July 23, 1911. The lengths of these specimens were in order of magnitude, 25 mm., 26 mm., 31 mm., 32 mm., 42 mm., 42 mm., and 46 mm., respectively. On a shallow reef east of Loggerhead Key, where observations and measurements of the gorgonians have been made for the past two years, there were found 15 specimens of *P. flexuosa* less than 50 mm. in length. These also were not present, or, at least, not large enough to be recognized in July 1911.

Observations made in June and July of 1910 and 1911 showed that all female specimens of *P. flexuosa* examined contained ripe eggs and that they could be caused to segment by the ordinary methods of inducing artificial parthenogensis, while all specimens examined this season after August 15 had given off their sexual products. On the basis of these observations it seems certain that these small specimens are practically one year old. The fact that they are all of nearly the same size would indicate also that the breeding season is of comparatively short duration.

Upon the above-mentioned reef, east of Loggerhead Key, there were found also 26 specimens of *G. flabellum* less than 65 mm. in height, which were not recognizable when all of the specimens upon that reef were measured in July 1911. As these specimens are approximately one year old, the records of the specimens put out upon tiles in July 1911 makes it possible to carry the growth record for this species to the end of the second year.

On any reef where *G. flabellum* occurs in large numbers the conformation of the individuals to a series of sizes is very noticeable. This was very clearly shown when 170 specimens growing upon a single small reef were arranged in series according to their heights.

After the group of small individuals less than 65 mm. in height, the next large group centered about a height of 220 mm., with less than a dozen specimens of intermediate sizes. The absence of an intermediate group, centering about 150 mm., would indicate that very few planulæ became attached during the summer of 1910, or, as is more probable, that the very young individuals were unable to withstand the effects of the violent wave-action developed during the hurricane of October 17, 1910. The next, and on this particular reef at least, the largest group centers about a height of 280 mm. Among the specimens over 300 mm., the "steps" were not so well marked, although the largest specimens (600 to 750 mm.) were separated by a considerable interval from those of the next smaller size. Among the specimens of *P. flexuosa* on this reef there was also a marked absence of individuals which from their size would appear to be two years old.

REGENERATION EXPERIMENTS.

The results of the regeneration experiments recorded in the report for last season* showed the general results from the operations upon a number of specimens of 3 species of gorgonians. In every instance it was found that after another year there had been little change in the specimens under observation. Where the upper portion had been cut from the "leaf blade" of *G. flabellum* there is now no evidence of the injury, as the injured "blade" has taken on the usual shape. Those specimens from the blade of which window-like openings had been cut out still show, after two years, the shapes of the pieces removed, and there has been no ingrowth from the periphery of the opening left after the removal of the tissue in the operation. In general there has been only the covering up of the exposed deeper tissues, but no extensive regeneration.

Where the living tissue was cut from one side of the stem of *P. flexuosa*, the polyps which make their appearance on this denuded area do not form a normal calyx, so that when they are retracted the stem appears smooth instead of roughened, as in normal specimens.

The larger branches of *Gorgonia acerosa* from which the polyp-bearing tissues were removed are still covered only by the scar-tissue first formed, in which no new polyps have made their appearance.

The results of all the regeneration experiments confirm the observations upon the recovery from injuries received naturally, namely, that while injuries to the actively growing portions of the colony (smaller branches or edges of blade in *G. flabellum*), are soon repaired and rendered unrecognizable, the injuries of older portions of the colony are, on the other hand, simply healed over without any restitution of the normal structure.

BREEDING OF PALYTHOA.

Having been unable to obtain ripe eggs of *Palythoa* previous to August 7, when the laboratory was closed for the season of 1911, arrangements were made to have Mr. W. L. Wilson, the collector, continue the observations during August and September. These observations showed that the greater

* Carnegie Institution of Washington Year Book No. 10, pp. 143-145.

part of the sexual products were given off during the interval between August 21 and 28. During the present season no ripe eggs have been secured up to August 29, and the apparent condition of the gonads is in no way different from that prevailing during late July and early August of last year.

Investigations on Echinoderms at Montego Bay, by H. L. Clark, of Harvard University.

While enjoying the privileges of the laboratory of the Carnegie Institution of Washington at Montego Bay, Jamaica, in February and March, 1912, I carried on investigations along three different lines, material being collected in each case for further study.

The most important work was on the post-larval development of brittle-stars (*Ophiuroidea*), knowledge of which is greatly needed for use in clearing up the phylogenetic history of the group. Of one species (*Ophiactis savignyi*) material was obtained in abundance, the adult brittle-stars and their young occurring in large numbers in the cavities of a red sponge which grows on mangrove roots at the Bogue Islands. While this is a common and well-known ophiuran, nothing has hitherto been published about its development. After the early larval stages are past and the adult form is assumed, asexual reproduction by fission across the disk occurs more or less repeatedly. As a result specimens with two arms or with three arms, with or without visible rudiments of three additional arms, or with the latter more or less fully developed, are constantly met with, while full-grown specimens have either five or six equal arms. Sufficient material of this interesting species was obtained to make possible the complete working out of its asexual reproduction.

Material was also obtained, though not in such quantity, for the study of the post-larval development of *Ophiothrix angulata* and of a species of *Amphipholis*. It was hoped that similar material might be secured for the study of the post-larval development of some holothurian, but no one species was sufficiently common to make the collection of the desired stages possible. On the other hand, a starfish (*Linckia guildingii*) proved to be unexpectedly common and a considerable amount of interesting material was secured. It has long been known that *Linckia* can throw off an arm, under proper stimulus, and that the arm so severed will develop a new disk with the normal number of rays. But evidence was secured at Montego Bay which seems to show that this is a general and normal method of reproduction in the species and is not dependent on any unusual stimuli or unnatural conditions.

The echinoderm fauna of the region adjacent to the laboratory was studied as thoroughly as shore-collecting permitted. Satisfactory dredging was not feasible. The reef collecting proved very rich, however, and much interesting material was gathered. In all 57 species of echinoderms were found, of which 10 were starfishes, 13 echini, 16 holothurians, and 18 brittle-stars. Of the starfishes, the most interesting were two exceptionally large specimens of 9-rayed *Luidia senegalensis*, with disks exceeding 60 mm. in diameter. They were caught on lines set for fish in 30 fathoms and were said to have swallowed both bait and hook. Some very finely colored specimens of *Stegnaster wesseli*, *Asterina folium*, and *Luidia clathrata* were preserved with the retention of most of their natural beauty by being rapidly dried, after killing and hardening in a solution of corrosive sublimate and formalin. Of the echini, the most notable was a species of *Schizaster*, a genus not hitherto known from Jamaica and previously taken in the West

Indies only in deep water. Among the brittle-stars, the most important capture was a fine specimen of the rare and little-known *Ophioderma guttata*. Of the holothurians, an apparently undescribed species of the genus *Holothuria*, pure white in color, is remarkable for the large amount of sand which uniformly and persistently adheres to the body-surface. In killing holothurians, and indeed all echinoderms, Mayer's method of narcotization, by placing the animals in a molecular solution of magnesium sulphate, was found invaluable, proving satisfactory in every case.

Studies of Foraminifera of Montego Bay, Jamaica, by J. A. Cushman, Boston Society of Natural History.

The study of the development of the various species of *Orbitolites*, especially the early stages, resulted in the finding of the actual megalospheric young in the outer chambers of the parent test, and the young also settling down in nearly all the early stages. Material was preserved for the further study of the cytological conditions in the megalospheric form. No microspheric sexual young were found at this season. A paper is in progress showing the comparative acceleration of development in the different species of *Orbitolites* based largely on this material.

I also collected foraminiferal material from shore out to 10 fathoms, under varying conditions, from the sand of the reefs to the muds of the Bogue Islands. As a result, a series is available for study which will give an adequate idea of the littoral foraminiferal fauna of a typical tropical shore of the West Indies. This is a preliminary step in the work which it is hoped may be carried into deeper waters in the same region and which will then afford accurate and detailed data for the comparison with foraminiferal deposits of the later geological periods of our Coastal Plain and the regions surrounding the Caribbean Sea. The conditions under which those deposits were laid down are now merely a matter of conjecture and their relation to other fossil-bearing beds largely problematical.

The Structure of the Spermatophores of Octopus, by Gilman A. Drew, Resident Assistant Director of the Marine Biological Laboratory at Woods Hole.

The structure of spermatophores must be correlated with their function and manner of discharge. Having studied the structure and manner of ejaculation of the spermatophores of the squid, and having observed the way in which they are placed in position by the dextrous movement of one of the arms of the male, it was particularly enlightening to study the spermatophores of another animal whose habits differed from those of the squid.

It is well known that the third right arm of the male *Octopus* is modified and has a groove along one side from its base to its tip. The extreme end of this arm in the species found in Montego Bay differs in shape and structure from the ends of the other arms and receives on its inner face the end of the groove referred to. It is supposed that spermatophores are passed down this groove during copulation and are placed in position by the tip of the arm. As the method of transfer is so different in the two forms, some difference in the structure of their spermatophores is to be expected.

The study of Cephalopod spermatophores is not new, but there seem to be very few forms that have been exhaustively studied and comparisons of different forms are generally enlightening. My studies of this form are

only begun, but it is evident that the spermatophores, while exceptionally large, are not so complicated as those of the squid. The spiral thread so conspicuous in the ejaculatory apparatus of the squid spermatophore is much reduced, the cement which forms so definite a part in the former is absent, and there are other interesting and possibly important differences that will receive attention later.

Report of Investigations on Marine Bacteria carried on at Andros Island, Bahamas, British West Indies, in May 1912, by G. Harold Drew, Cambridge, England.

The work described in this report was a continuation of that begun in 1911 at Port Royal, Jamaica, and at Tortugas. These former investigations were summarized in the report of the Director of the Department of Marine Biology of the Carnegie Institution of Washington for 1911, but in order to make clear the objects of the present work it will be necessary to recapitulate briefly some of the chief conclusions arrived at in the former report. In this it was shown:

(1) That in the seas of the American tropics bacteria exist, which possess the power of breaking down the nitrates in sea-water, first to nitrites, and ultimately to free nitrogen. Traces of ammonia are formed in this process, but the amount is never considerable; it would seem probable that there is a mutual decomposition between the ammonia and nitrites formed, giving rise to the evolution of free nitrogen. In fluid culture media these bacteria rapidly cause the complete destruction of nitrates which were contained in the media, leaving no trace of either nitrate or nitrite. It was suggested that the presence of these denitrifying bacteria, by keeping the nitrate concentration of the sea-water down to a minimum, would account for the relative scarcity of phyto-plankton in the tropics, and this in turn would account for the scarcity of zoo-plankton, which ultimately depends on the phyto-plankton for its food-supply.

(2) That these denitrifying bacteria possess the power of precipitating soluble calcium salts in the form of calcium carbonate from sea-water. It was suggested that the thick deposits of fine chalky mud found in the Marquesas Keys and in other places along the Florida coast are now being precipitated by bacterial agency, and that similar bacterial action may have played an important part in the formation of chalk and other limestone rocks in geologic times.

The object of the work at Andros Island was to investigate the vertical distribution of marine bacteria in the deep water of the Tongue of the Ocean, and to study the bacterial flora of the immense flats of chalky mud forming the shallows off the west coast of the island, with a view to obtaining additional data as to the precipitation of calcium carbonate by bacterial agency in the sea.

The Tongue of the Ocean is a narrow strip of deep water, some 150 miles long, entirely inclosed by land or shallows except at the northern end, where it joins the New Providence Channel. The greater part of its western margin is formed by the coast of Andros, and it was at Golding Cay, at the mouth of the South Bight of Andros, that the laboratory was established. This position was especially suitable for the work, as by running out a few miles in a direction at right angles to the coast-line the middle of the Tongue of the Ocean could soon be reached, and also the mud flats to the west of the island were readily accessible by water, as the South Bight runs right

through the island to the west coast. The depth of the Tongue of the Ocean varies from 1,200 fathoms at its mouth to about 740 fathoms at its southern end. Off Golding Cay the depth varied between 800 and 850 fathoms in different localities. The submarine slope off Andros is very abrupt and in places must be nearly perpendicular a few yards from shore, but the slope on the south and east margins of the Tongue is less steep. The tides are not strong, the average rise and fall being from 2 to 3 feet; currents are slight and variable, and would appear to depend on the prevailing winds. The surface-water of this region, except along the Andros shore, is everywhere continuous with that overlying the thousands of square miles of shallows forming the Great Bahama Bank and the flats and cays lying to the west of the Exuma Islands, whereas the deeper water is only connected with the outer ocean by the comparatively narrow entrance between New Providence Island and the north of Andros.

Andros Island consists of a limestone formation, the exact nature of which is dealt with by Dr. T. Wayland Vaughan in another part of this publication. The greater part of the island is very flat and is only elevated a few feet above the sea-level; a few irregular undulations, never more than 100 feet high, are found, especially along the east coast. There is evidence to show that formerly the level of the land was much higher than at present, and signs of rapid erosion of the rock are everywhere obvious.

One of the most remarkable features is the absence of soil, even in the well-wooded parts of the island, the trees and bushes growing directly out of crevices and holes in the rock and giving rise to practically no leaf-mold. In the numerous "potholes" which occur all over the island a small deposit of black leaf-mold can be found, and these "potholes" are the only suitable places for cultivation.

The erosive action of water on the rock is especially noticeable where the slow drainage from an inland swamp can be traced in its course to the sea. In such a locality the hard rock is eroded, honeycombed, and undermined to a most remarkable degree, even though the amount of drainage, except after the heaviest rains, can scarcely be more than a slow trickle.

Erosion of the rock along the coast, where it is exposed to the action of the sea-spray, is also very marked. From the occurrence of this erosion, it is obvious that all the water draining from the land into the sea must contain a large proportion of calcium salts in solution. Towards the west coast of the island the land is remarkably flat, and near the coast consists of white, chalky mud which has partially dried and in places has formed a harder crust on the surface. These half-dried mud-flats slope almost imperceptibly into the sea, and are continuous with the submarine flats which extend for 60 miles or more off the west coast at an average depth of not more than 2 fathoms. The mud forming the submerged flats is very soft, and near the coast it was easily possible to push a 12½-foot sponge-pole down to its full length into it without touching any harder material. The surface layer of the mud for a depth of about 6 inches is of a creamy white color, but below that it is of a grayish tinge and has a slight odor of sulphureted hydrogen. Unfortunately there was no opportunity of obtaining information as to the real thickness of this layer of mud, nor of investigating more than the surface layers at any distance from the coast.

The apparatus employed by previous workers for obtaining samples of water for bacterial examination from the deep sea has either consisted of some sort of water-bottle made of metal, or else of exhausted glass bulbs with a neck drawn out into a capillary tube which could be broken off at the

depth from which a sample was desired. Recent work on the bactericidal effects of metals suggested that it was undesirable to employ a water-bottle the receiver of which was made of metal, and some test experiments were made which conclusively showed that for the collection of samples of sea-water neither copper, brass, aluminum, bronze, silver, nor nickel were suitable metals, and indeed that a very large proportion of the bacteria were killed by exposure to the action of these metals for an hour or more. The use of exhausted glass bulbs presents considerable difficulties for depths as great as 800 fathoms. The bulbs must be strong and very thoroughly annealed, as otherwise the slight shock caused by breaking off the capillary neck is liable, under the great pressure, to make the bulb fly into small fragments. Another great disadvantage is the strong probability that the sudden reduction in pressure to which the water is exposed as it enters the bulb would immediately kill any bacteria in the water.

In order to overcome the difficulties presented by the use of either of these types of apparatus, a water-bottle on a new principle was designed for me by Mr. D. J. Matthews, hydrographer to the Marine Biological Association of the United Kingdom and to the Irish Fisheries Board. The container of the bottle consisted of a strong glass cylinder, with ground ends, holding about 250 c. c. This was closed at each end by rubber washers through the center of which a short piece of thin-walled rubber tubing passed, the tubing being sealed at the end within the cylinder. An apparatus was arranged with which, by sending down two messengers, the cylinder could first be opened and then closed at both ends at any required depth in the sea. The whole apparatus was first sterilized by steaming in a "Koch," and then the cylinder was completely filled with 95 per cent alcohol. The washers were kept tight on the ends of the cylinder by strong springs, so that no leakage occurred.

When the cylinder was opened by sending down the first messenger, the alcohol, being of lower specific gravity than sea-water, diffused out almost instantaneously, causing an upward current of water to flow through the cylinder, which was then closed by the second messenger and hauled to the surface with its contained sample of water. The washers with their attached pieces of thin rubber tubing had sufficient capability of bulging inwards to allow for contraction of the alcohol due to the low temperature at any considerable depth, and to its compressibility being greater than that of sea-water; and similarly the expansion of the sample of water as the apparatus was hauled up was compensated for by the partial collapsing of the thin-walled rubber tubing.

It is obvious that even had a slight amount of leakage occurred, a leakage inwards during the descent of the apparatus would not vitiate the results, as bacteria would promptly be killed in the 95 per cent alcohol; similarly, on hauling up, the leakage, if any, would be outwards, due to the expansion of the sample through the regularly increasing temperature, and so the sample would not be contaminated by any of the surface layers through which it was hauled. There was, however, no reason to suppose that any leakage occurred.

After the first sterilization by steaming, the action of the alcohol was relied on for sterilization between successive samples, and both experimentally and in practice this method was found to be absolutely safe, as all the marine bacteria are very readily killed by the action of alcohol and they do not form resistant spores. After the collection of a sample it was siphoned off into a sterilized glass bottle by means of a sterilized length of rubber tubing.

A detailed account of this apparatus, which would be out of place in this report, will be published with full diagrams in vol. IX, No. 4 of the Journal of the Marine Biological Association of the United Kingdom, by Mr. D. J. Matthews.

For taking soundings and obtaining bottom samples one of the "snapper-rods," disengaging a 30-pound weight, as made by the Telegraph Construction and Maintenance Co., of London, was used in conjunction with a spring-balance which indicated the decrease in tension of the wire on disengaging the weight.

The temperature at the depth at which the samples were taken was recorded by reversing thermometers made by Messrs. Negretti & Zambra, of London. These thermometers were tested and corrected by the National Physical Laboratory at Teddington, England. They were provided with auxiliary thermometers sealed within the same outer glass tube as the reverser, so that the correction that it is necessary to make for the difference in the temperature at which the reversal took place and that at which the thermometer is read could be easily applied. The volume of the upper bulb of the reverser, expressed in degrees of the stem at 0° C. (Vo), was engraved on the back of the stem of each reverser, so that all the data were at hand for making the correction in accordance with the formula $\frac{(t-t')(Vo+t)}{6,300}$ where $t=$ the temperature recorded by the reverser and $t'=$ the temperature shown by the auxiliary thermometer at the time of reading.

The mechanism by which the thermometer frames were reversed was part of the water-bottle apparatus.

The chief culture media employed were the following:

I. *Peptone Agar:*

Peptone (Witte's)	2.0 grams.	*Remarks:* This medium was used in the routine plating of the samples, for making counts. It solidifies at about 38° C.
Potassium nitrate (KNO_3).	0.5 gram.	
Sea-water	1,000.0 c. c.	
Agar agar	18.0 grams.	

II. *Gran's Medium:*

Potassium nitrate (KNO_3).	0.5 gram.	Calcium malate is only slightly soluble in water (about 1/20th per cent), and so can be added in excess.
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.	
Calcium malate ($C_2H_8(OH)<^{COO}_{COO}>Ca$) ...about.	5.0 grams.	
Sea-water	1,000.0 c. c.	

III. *Potassium Malate Agar:*

Potassium malate ($C_2H_3(OH)<^{COOK}_{COOK}$)	1.0 gram.	This medium was only filtered through glass wool, so that a very slight precipitate of calcium phosphate was retained.
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.	
Potassium nitrate (KNO_3).	0.5 gram.	
Agar agar	18.0 grams.	
Sea-water	1,000.0 c. c.	

IV. *Calcium Succinate Medium:*

Calcium succinate ($C_2H_4<^{COO}_{COO}>Ca$	2.0 grams.	This medium was boiled and filtered to remove the slight precipitate of calcium phosphate before sterilization; with the addition of phosphate it gave a more vigorous growth than if omitted.
Potassium nitrate (KNO_3).	0.5 gram.	
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.	
Sea-water	1,000.0 c. c.	

V. *Calcium Acetate Medium:*

Calcium acetate ($Ca(CH_3COO)_2$)	5.0 grams.	Boiled and filtered before sterilization to remove precipitate of phosphate.
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.	
Potassium nitrate (KNO_3)	0.5 gram.	
Sea-water	1,000.0 c. c.	

VI. *Peptone Calcium Acetate Medium:*

Calcium acetate ($Ca(CH_3COO)_2$)	5.0 grams.
Peptone (Witte's)	0.2 gram.
Potassium nitrate (KNO_3)	0.5 gram.
Sea-water	1,000.0 c. c.

Media IV, V, and VI were also made up with the addition of 0.2 gram of magnesium tartrate per 1,000 c. c.

The fluid media were made in 1,500 c. c. flasks, and 1,000 c. c. of medium was used for each culture. Owing to the high temperature and the lack of ice it was not practicable to employ gelatin media.

It will be convenient to consider the investigation of the bacteriology of the deep water of the Tongue of the Ocean and that of the chalky mud flats to the west of Andros separately.

BACTERIAL INVESTIGATIONS IN THE TONGUE OF THE OCEAN.

Continued bad weather during the whole of our stay at Andros considerably added to the difficulties of this work, and on this account it was only found possible to work three stations. The last two were worked under the most disadvantageous conditions, the quick roll of the boat making the filling of the water-bottle with alcohol and the siphoning off of the sample under sterile conditions a matter of the greatest difficulty.

The first station worked was situated 6 miles due east of Golding Cay, the second 14 miles due east of Golding Cay, and the third station 10 miles ENE.¼E. of Golding Cay.

At the first station, worked on May 8, bottom was sounded at 822 fathoms. The sea was calm at first, with a SSE. swell, but became choppy later. The wind was SSE., force 0 to 1 at 8^h 30^m a. m., but freshened considerably later in the day. The sample of the bottom obtained by the snapper-rod consisted of a sticky white ooze, composed of very minute unorganized particles of calcium carbonate, and containing pteropod and globigerina shells. The following temperatures were recorded:

Depth.	Temperature.	Depth.	Temperature.
	° C.		° C.
Surface	26 90	200 fathoms	17.13
10 fathoms	25.90	400 fathoms	8.98
50 fathoms	25.14	600 fathoms	4.70
100 fathoms	22.00	Bottom (822 fathoms)	3.97

These samples without previous dilution were plated in peptone agar, 1 c. c. of the sample being used for each plate. The agar was cooled to 40° C. before plating. It is very necessary that this temperature should not be exceeded, as many of the marine bacteria are very sensitive to heat. The use of agar at a temperature of 45° C. will cause the death of a large proportion of the bacteria, though in the process of plating they can only be exposed

to this temperature for a very short time. The cultures were kept in the dark at the room temperature (averaging about 28° C.), and at the end of 24 hours a free growth of colonies was apparent. At the end of 48 hours the plates were counted with the results below. From these counts it is apparent that the number of bacteria falls off at some point between 200 and 400 fathoms.

Depth.	Colonies developing from 1 c c. of sample.	Depth.	Colonies developing from 1 c.c. of sample.
Bottom (822 fathoms)...............	0 3 1	200 fathoms............................	*160 *100
600 fathoms..............................	17 14	100 fathoms............................	(†)
400 fathoms	15 16	50 fathoms............................	(†)
		10 fathoms............................	(†)
		Surface....................................	

* Very much overcrowded, indications of presence of many more colonies which have not been developed owing to overcrowding.
† Uncountable owing to overcrowding.

The second station was worked on May 11, at a point 14 miles due east of Golding Cay. The sea was calm at first, and the wind ENE., force 1, but later in the day a heavy swell set in and the wind freshened to about force 4; eventually the weather became so bad that it was impossible to work and the station had to be abandoned before it was completed. Bottom was sounded at 890 fathoms, but there was some stray on the wire, so that the true depth was probably about 825 fathoms as shown by the chart. The bottom consisted of fine white calcareous ooze; no pteropod but some globigerina shells were seen. The following temperatures were recorded:

Depth.	Temperature.	Depth.	Temperature.
	° C.		° C.
Surface..................................	26.30	200 fathoms............................	17.42
10 fathoms............................	26.40	300 fathoms............................	14.32
50 fathoms............................	24.89	400 fathoms............................	9.79
100 fathoms............................	22.63	Bottom	4.15

Samples down to a depth of 200 fathoms were diluted 1 in 100 with sterilized sea-water before plating. The following results were obtained after 48 hours' growth. The figures represent the mean of the number of colonies developing in the two plates that were made from each sample. It is here apparent that the number of bacteria per cubic centimeter falls off very rapidly between 200 and 300 fathoms.

Depth.	Colonies developing from 1 c.c. of sample.	Depth.	Colonies developing from 1 c.c. of sample.
Surface..................................	16,200	100 fathoms............................	14,000
10 fathoms............................	13,100	200 fathoms............................	15,000
50 fathoms............................	14,000	300 fathoms............................	14
		400 fathoms............................	12

The third station was worked on May 23 at a point 10 miles ENE.¼E. of Golding Cay. The wind was east, of about force 4. As it had been

blowing for the previous 10 days without intermission the sea was so rough that it was only possible to work when steaming slowly ahead into the wind. This resulted in a great deal of stray on the sounding wire, so that the number of fathoms of wire run out is greater than the actual depth at which the samples were taken; these differences will be large for the more superficial samples, but small at greater depths, as the wire strays in a curve whose gradient becomes very steep a little below the surface under these conditions. The following temperatures were recorded:

Length of wire run out.	Temperature.	Length of wire run out.	Temperature.
	°C.		°C.
Surface	27.10	160 fathoms	18.83
20 fathoms	26.50	250 fathoms	14.98
100 fathoms	22.80	350 fathoms	10.85

At this point the station had to be abandoned, owing to the bad weather. The samples down to 160 fathoms were diluted 1 in 100 with sterilized sea-water before plating in peptone agar; the remaining two were plated undiluted. At the end of 48 hours the following counts were made, the numbers representing the mean of the number of colonies in the two plates made from each sample.

Length of wire run out.	Colonies developing from 1 c.c. of sample.	Length of wire run out.	Colonies developing from 1 c.c. of sample.
Surface	15,000	160 fathoms	13,000
20 fathoms	15,500	250 fathoms	14,300
100 fathoms	13,700	350 fathoms	16

The colonies developing in all the cultures were only of two kinds, the denitrifying and the non-denitrifying species, both described in my former report. The non-denitrifying species formed a relatively small proportion of the total, and they were not found at all in any cultures made from samples taken below 250 fathoms. As they appear to be comparatively chemically inactive, and as nothing is at present known concerning the part played by them in the metabolism of the sea, they will not be further considered here.

For the denitrifying species I propose the name of *Bacterium calcis,* owing to their power of precipitating calcium carbonate from solution in the sea. This property will be considered more fully later in this report. The chief cultural characteristics of *B. calcis* were described in my former report, but it will be as well to repeat them here.

On potassium malate, or peptone agar media, colonies are visible as minute white specks after 6 to 8 hours when the room temperature averages 29.5° C. After about 18 hours the colonies are well developed, they are white in color, circular, but with finely irregular outline, and have a granular appearance. Superficial colonies are much elevated at first, but as growth proceeds spread rapidly over the surface of the agar. The deep colonies remain small, circular, and discrete. Growth is somewhat more rapid on the peptone agar than on the potassium malate agar, and the older colonies develop a brownish tinge in the center when growing on the former medium.

On gelatin peptone (5 per cent peptone, kept at between 20° and 25° C. to insure the medium remaining solid) growth was very slow. In stab cultures growth proceeded slowly from the surface downwards, forming a funnel-shaped depression of liquefied gelatin. Acid formation occurs in glucose, mannite, and cane sugar, but not in lactose media.

Growth is totally inhibited at a temperature of 10° C., but takes place slowly at 15° C.

Growth is much retarded by exposure to bright sunlight, but the bacteria are not killed by a 10-hours exposure.

The bacteria are facultative anaërobes, but growth under anaërobic conditions is very slow.

On Gran's medium growth is vigorous, and is accompanied by rapid destruction of the nitrate present. No growth occurs if the potassium nitrate be omitted or if the calcium malate be replaced by calcium carbonate. Growth in a pure solution of peptone in sea-water is slight, but becomes abundant if potassium nitrate be added, when denitrification quickly ensues.

A consideration of these results obtained in the Tongue of the Ocean shows that the waters down to a depth of somewhere about 300 fathoms in April 1912 contains an enormously larger number of bacteria than the water in the neighborhood of Tortugas in June 1911. The number of bacteria falls off from about 14,000 to about 12 per 1 c. c. between depths of 250 and 350 fathoms; the temperature at 250 fathoms was about 15° C., and at 350 fathoms about 11° C., and it was shown in June 1911 at Tortugas that *B. calcis* will grow slowly at 15° C., but that growth is totally inhibited at 10° C. It would thus seem that the observed distribution of the bacteria agrees fairly with what might be expected from the temperature conditions.

The much greater abundance of bacteria in the surface-waters of the Tongue of the Ocean than in the waters around Tortugas may perhaps be accounted for by the fact that in the former locality by far the greater part of the surface-water must flow over the immense chalk mud-flats and shallows which bound it in most directions, and, as will presently be shown, these mud-flats are phenomenally rich in bacteria and are probably still being deposited by bacterial agency.

BACTERIAL INVESTIGATION OF THE CHALKY MUD-FLATS TO THE WEST OF ANDROS.

Samples of the mud were taken from the western entrance of South Bight and from points 2 or 3 miles out from the shore, practically identical results being obtained from all these localities. The sample at the mouth of the bight was taken in about 4 feet of water, that 2 miles out in 7 feet, and that 3 miles out in 8 feet. The surface layer of the mud for a depth of about 6 inches was of a creamy white color; below that it was of a grayish tinge with a slight odor of sulphureted hydrogen. Microscopically the mud consisted of minute unorganized particles, sometimes aggregated into larger soft masses of irregular shape. The samples were necessarily taken from the surface of the mud.

For bacterial examination one part of this mud was shaken up with three parts of sterilized sea-water. This was allowed to settle for 15 minutes, and then the clearer surface layer was diluted 1 in 1,000,000 with sterilized sea-water. The diluted fluid was plated in peptone agar, 1 c. c. being used for each plate. The count of a number of plates after 48 hours gave 40 colonies as an average, and thus the mud itself must contain a minimum of

$40 \times 4 \times 1{,}000{,}000 = 160{,}000{,}000$ bacteria per cubic centimeter. The actual number in the mud possibly far exceeds this figure, since a large proportion of the bacteria would probably settle with the larger particles after the first dilution. The bacteria found in these cultures were nearly all the *B. calcis*, previously described; only occasionally were a few colonies of the non-denitrifying species seen.

A sample of the water taken from the surface of the sea at a spot 3 miles out from the western entrance of South Bight gave a count of 35,000 colonies per cubic centimeter, the great majority of these being *B. calcis*.

Subcultures of *B. calcis* were made in Gran's medium and in the calcium succinate, calcium acetate, and peptone calcium acetate media, whose composition has already been given. Denitrification in all these media was rapid and eventually complete, and was accompanied by the precipitation of calcium carbonate. In the last three media, which contained no solid matter and were quite clear and transparent before inoculation, this precipitation was manifested after 12 hours by the formation of a thick white cloud in the fluid, readily distinguishable from the cloudiness produced merely by bacterial growth. The development of this precipitate continued rapidly during the first 48 hours, but in many cases it was composed of such fine particles that they showed little tendency to settle to the bottom of the flask. In other cases larger particles were formed and a sediment similar in appearance to the chalky mud of the mud-flats was produced. The exact conditions determining the size of the particles precipitated could not be ascertained, as the size varied largely in cultures made at the same time, in the same media, and kept apparently under the same conditions. The addition of magnesium tartrate in small quantities (0.2 gram per 1,000 c. c.) to the culture media seemed to induce the precipitation of larger particles, but it did not appreciably affect the rate of growth of the bacteria. In some of the older cultures, that had been kept for a week or more, the sides of the flasks were coated with a thin layer consisting of extremely minute rhombohedral crystals of calcium carbonate. Occasionally these crystals formed around small bubbles that had remained near the surface of the fluid, the weight of the crystals eventually caused the bubbles to sink, and then the contained gas became dissolved. In this way a number of small hollow spheres were formed, their walls consisting of minute crystals of calcium carbonate. The formation of these curious bodies occurred especially readily in the calcium succinate medium to which 0.2 gram of magnesium tartrate per liter had been added. The deposition of calcium carbonate in the crystalline form was only noted in old cultures, and then it was in an amount relatively extremely small when compared to the precipitate of unorganized and amorphous calcium carbonate.

A consideration of these observations shows firstly that *B. calcis* is found in enormous numbers in the chalky mud-flats of the Great Bahama Bank, and secondly that this bacterium is capable of precipitating calcium carbonate from fluid media containing soluble calcium salts. It would seem a fair deduction that these mud-flats have been precipitated by the action of *B. calcis* on the soluble calcium salts carried into the sea by drainage from the land, where extensive and rapid weathering of the limestone rock is in progress.

Preliminary Report upon Investigations, by A. J. Goldfarb.

SALINITY CHANGES AND THEIR EFFECTS UPON THE REGENERATION OF CASSIOPEA XAMACHANA.

The amputated oral arms of this large medusa served as a basis for the determination of the influence of changes of salinity of sea-water upon regeneration. With the containing vessels, quantity of solution, temperature, evaporation, extent of injury, size of medusa, and other factors uniform, the variable factors were reduced to two, namely, density of sea-water and amount regenerated. The use of distilled water for purposes of dilution and of sea-water concentrated by slow evaporation corrected certain errors in previous experiments of this nature.

There were 323 oral arms amputated at approximately the same level. After a month's interval the final measurements gave the following: Maximum regeneration did not occur in normal sea-water, but in water diluted 5 to 10 per cent. This is in accord with the author's previous work on hydroids. A more limited regeneration occurred both in normal sea-water and in dilutions of 10 to 15 per cent. In these three solutions regeneration was practically the same. With increasing dilution the amount regenerated decreased until a density of 55 was reached, beyond which no regeneration whatsoever occurred.

In contradistinction to the wide range of dilutions in which considerable regeneration occurred, even small concentrations appeared to be very injurious. In a density of 1.05 the amount regenerated was less than that in a 0.55 solution. Very little regeneration occurred in a density of 1.11 and 1.17, falling off rapidly in densities of 1.25 and 1.33, beyond which regeneration ceased altogether. In the latter solutions, furthermore, regeneration was atypic.

In its normal habitat *Cassiopea* is subject to considerable changes in salinity, for the density of the inclosed waters in which it lives is undoubtedly affected by the subtropical heat and rains. The exact changes in density of such inclosed waters and tide-pools is now being investigated by Doctors Mayer and Vaughan. One might have anticipated that *Cassiopea* would be less susceptible to changes in density, under experimental conditions, than hydroids living in the open sea, where the density is practically constant. It nevertheless regenerates exactly like these hydroids.

REGENERATION OF THE ANNELID WORM AMPHINOMA AFTER REMOVAL OF THE NERVE-CORD.

The following investigation was undertaken in order to ascertain whether the regeneration of the head of the earthworm in the absence of its nerve-cord was a phenomenon peculiar to the earthworm and of no further significance, or whether other annelid worms living under different environmental influences and unrelated to it would regenerate their heads under the same conditions, and thus support the view that regeneration in adult animals is independent of nervous stimuli.

Two methods for the removal of the nerve-cord of *Amphinoma* were employed. First, a so-called "window" was removed from the ventral anterior portion, including muscle-layers, dissepiments, nerve-cord, nephridia, etc.; second, the nerve-cord was removed with forceps in such a manner as not to injure or only slightly injure the adjoining tissues. The latter method had been successfully employed in experiments upon *Lumbricus*. The worms

were operated on at various levels, as follows: A portion of the nerve-cord was removed from 102 worms; a portion of the intestine was removed from 26 worms; controls, 151 worms.

After ordinary amputation, regeneration was first observed about the fifteenth day. After removal of the nerve-cord, 23 or more days were required before regeneration was observed. In spite of the large mortality among worms with the nerve-cord removed (40 per cent), and though enough time was not given for some of the more seriously injured ones to regenerate, about 37 per cent of the animals did regenerate a perfectly differentiated head, segments, and series of complex appendages.

The worms were prepared for further examination of the operated region in order to ascertain definitely whether the nerve-cord had been regenerated in the interval. It is highly probable, on the basis of studies on *Lumbricus*, that the head and segments of *Amphinoma* regenerated in the continued absence of motor stimuli, exerted by or through the nerve-cord.

A NEW METHOD FOR THE PRODUCTION OF FUSED LARVÆ.

The Herbst-Driesch method for the production of fused embryos and larvæ has been used by several American investigators with *Arbacia* eggs, without positive results. The writer succeeded only after modifying this method as described in a recent publication. Neither the original nor the modified methods were effective with sea-urchins common at the Tortugas, namely, *Diadema, Toxopneustes,* and *Hipponoë.*

With *Toxopneustes* eggs the following method was finally used, which gave rise to large numbers of fused plutei and which involved no disturbing physical changes as with former methods. After fertilizing the eggs, they were placed in sea-water, to which enough 5/8 molecular NaCl was added to make solutions ranging between 35 and 75 per cent; for example, a 35 per cent solution consists of 75 c.c. of 5/8 molecular NaCl added to 125 c.c. of sea-water. The eggs were left in this solution about 6 hours and were then transferred to normal sea-water. The unfused larvæ floated to the surface, the fused ones remained at or near the bottom.

I am unable at this time to give an exact statement of the number of fused larvæ produced in this way, though it appeared that it greatly exceeded the number obtained with *Arbacia.* If on further examination this is found to be correct, the method above outlined can claim the distinction of producing the largest number of fused echinoid larvæ on record. The types of fusion were essentially the same as those heretofore described.

Whether the other echinoid eggs could be made to fuse by the same method was not determined, on account of the absence of sufficiently ripe eggs and sperm during the months of July and August.

VARIATIONS IN ECHINODERM LARVÆ INDUCED BY CHEMICAL AND PHYSICAL CHANGES.

The present inquiry undertook to determine to what extent the number of variants under normal conditions would be increased or new variants produced, and under what conditions maximum and minimum effects would appear after shaking or centrifugalizing eggs, or after the use of weak NaOH solutions, NaCl, $MgSO_4$, LiCl, CO_2, evaporation, density of sea-water, overcrowding, and maturity of eggs and sperm.

THE INFLUENCE OF CHANGES IN DENSITY.

It was found that, depending upon the type of vessel and the quantity of sea-water used, the evaporation varied as much as 50 per cent or more in 24 hours. In one experiment, for example, the evaporation after 24 hours was as follows:

Type of vessel and quantities of sea-water (c.c.).	Loss by evaporat'n.	Density of sea-water.	Type of vessel and quantities of sea-water (c.c.).	Loss by evaporat'n.	Density of sea-water.
Finger bowls:	*p. ct.*		Finger bowls:	*p. ct.*	
25	68	3.12	400	10	1.11
50	41	1.69	500	7	1.07
100	26	1.35	Syracuse dishes:		
200	12	1.13	20	44	1.78
300	13	1.14	10	40	1.66

It was found that in concentrations to 1.13 or 1.14 either the variants were not increased in number and kind or only slightly so. Beyond this concentration, however, the plutei were increasingly irregular and atypic, though of the same general type as those in control solutions. While the above figures are not absolute, they do show that in finger-bowls ordinarily used in this kind of experimental work not less than 200 c.c. of sea-water should be used. With less volume the concentration due to evaporation under the conditions of temperature and humidity at Tortugas was so great that the number of variants was greatly increased, the number and range depending upon shallowness of dish, surface exposed, number of eggs, etc.

In other experiments fertilized eggs were placed in sea-water whose densities were changed either by addition of distilled water or by slow evaporation to give the following series:

0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.00, 1.05, 1.11, 1.17, 1.25, 1.33

The number and types of variants and normal plutei found in normal sea-water were likewise found in a wide range of solutions from 0.80 to 1.11. Beyond these limits the number of variants increased with increasing changes in density until 1.17 or 1.25 was reached on one side, and 0.75 or 0.70 on the other. When the densities exceeded these limits the eggs rarely developed into plutei, but most frequently died during cleavage.

THE INFLUENCE OF CO_2.

The presence of CO_2 was extremely injurious, whether its source was the respiratory products of developing eggs or manufactured gas. The CO_2 was toxic even in small doses. Few or no eggs developed in sea-water containing more than 7.5 per cent carbonated sea-water. Development was retarded or incomplete in solutions containing even 2.5 per cent of such carbonated water. The plutei were irregular even in a 1 per cent solution, but these irregularities were of the ordinary type.

Overcrowding made for increased variation, and by suitable experiments it was determined that for a volume of 200 c.c. of sea-water not more than 0.125 to 0.375 c.c. of eggs could be used, *i. e.,* about 0.0006 to 0.0018 of the entire volume, without introducing increased variability. In such numbers the variants were reduced to a minimum. By increasing the number of eggs or decreasing the volume of water the number of variants was correspondingly increased.

THE PRODUCTION OF VARIOUS ATYPIC LARVÆ.

Special interest attaches to those experiments wherein new types of variants were produced. With lithium-chloride solutions of the proper concentrations, namely, 1.5 to 2 per cent molecular solution, the characteristically extruded enteron type of gastrula described by Herbst was readily obtained in large numbers. That no specificity obtained between the lithium chloride and this particular variant is shown by the fact that with a 25 to 30 per cent molecular $MgSO_4$ solution in sea-water, large numbers of gastrulæ with extruded entera were also obtained. The same effect was produced by a 50 to 60 per cent 5/8 molecular NaCl solution. The detailed study of these gastrulæ is now being made.

An armless type of variant was produced in a 7.5 per cent molecular NaCl solution. This same variant was also found in an isotonic solution, namely, 60 per cent of a 5/8 molecular NaCl solution in sea-water. That this variant is due neither to the Na nor to the Cl ions is shown by its formation in large numbers in a 15 to 25 per cent molecular $MgSO_4$ solution. As two of the solutions were isotonic with sea-water the result could not have been due to an osmotic effect.

A new type of variant not heretofore described was produced in a molecular $MgSO_4$ solution, a type in which the oral and aboral arms were bent from their almost parallel position until they extended in almost opposite directions. The change in position and relative lengths of arms and body resulted in a pluteus containing a straight tripartite enteron and a body about twice the normal size.

Report upon Montego Bay, Jamaica, as a Collecting Station for Marine Animals, by G. M. Gray, Curator of the Woods Hole Laboratory.

Montego Bay, Jamaica, is a rich collecting-ground for the naturalist, the reefs and beaches being readily accessible. The climate is mild and work may be accomplished under excellent conditions. The water, even in winter, is such that one can wade over the reef-flats for hours at a time without injurious results. The region is especially rich in echinoderms, a large number of species being obtained, some of which are abundant in numbers. Many species of corals are found upon the scattered reef-patches. Actinozoa and tube-dwelling annelids are numerous, and in no other place have I seen such an abundance of *Octopus*. I was at first rather disappointed in the number of shell-bearing Mollusca obtained, but as we became more familiar with the region a greater number and variety of forms were captured. Fish of many kinds appeared to be numerous. Some curious and beautiful crustacea are to be found here, including marine, fresh-water, and land forms.

In the month spent at Montego Bay we could obtain only an insight into the chief characteristics of the fauna, but the whole region is worthy of a careful and extended investigation. Owing to lack of facilities our collecting was confined to the shores and to the shallow water, yet within 5 miles of the mouth of Montego Bay the sea is 2,000 fathoms in depth.

Summary of Work Done on the Fishes of Tortugas, by E. W. Gudger, State Normal College, Greensboro, North Carolina.

Especial attention was given to the breeding habits of the nurse-shark, *Ginglymostoma cirratum*, which was found in considerable numbers in a sandy bay in Bush Key, east of Fort Jefferson. A number were captured, photographed, measured, and dissected. The females were all found to have

the hinder edges of their pectorals much frayed, battered, and seemingly bitten, while the fins of males were later found to be intact. When the breeding habits were studied the matter became clear. Fertilization is internal, and as a preliminary step to the process of copulation the male grasps the hinder edge of the pectoral fin of the female with his mouth. It seems to be a matter of indifference which fin he lays hold of. His mouth being small and his teeth weak, the female not infrequently breaks away from him; hence the torn and scarred condition of her pectorals. The male at length subdues the female and, throwing her on her back with his body above, inserts his claspers into the lateral pockets of her cloaca and transmits the seminal fluid.

Dissection of the female reveals some interesting structures. The ovary is single and seemingly median, but study of several 15-inch specimens shows that this is the right ovary, the left having become atrophied. The right ovary with its great eggs has become enormously developed and has come to lie in the median line. These eggs, 2 to 2.5 inches in diameter, are somewhat flattened, yellow in color, and perfectly fluid. The oviducts are paired and in the anterior third each has an enlargement, the shell gland. Just behind each shell gland the oviduct is enlarged to form the uterus; but this, instead of being of uniform size throughout, as the writer has found in *Scoliodon terrænovæ, Sphyrna tiburo,* and other sharks, or swollen into a shape approaching semispherical, as in *Dasyatis say, D. hastata, Pteroplatea maclura,* and other rays, is enlarged throughout, but on the ventral side is developed into a conical enlargement containing the bulk of the eggs.

The inner surface of the uterus has the lining raised in folds or plaits about 0.5 inch wide. These are arranged in circular fashion, overlapping each other, like shingles on a roof. These plaits are not smooth, but have the surface broken up into short prolongations. Evidently we have here a means for oxygenating and feeding the young after they have broken out of the shell, but are still retained in the maternal uterus.

The large eggs are contained in large horny capsules, larger and thicker than any selachian egg-shells which the writer has yet studied. The average length of normal eggs is about 130 mm., girth 180 mm. Most of the eggs have blunted terminals which at times form stumpy prolongations, and in a few instances filaments as long as the egg-case proper are found, but these are readily detached.

The early blastoderms are exceedingly small, so much so that they would hardly be noticed but for their darker color, contrasting with the yellow yolk. Very old blastoderms have a projecting lip or edge which may be lifted from the underlying yolk by a needle. At one place an inpushing of the blastoderm rim is found and at the head of this the embryo is formed. About one-third of the series of embryos necessary for a study of the development has been obtained. Old embryos have long external gills, deep red in color. The filaments projecting from the spiracles are very short and of an intense red color.

The eggs taken from the uterus of the mother will continue their development in running salt-water. A number with late embryos were left at the laboratory at Tortugas on my departure on July 25. These were to have been preserved at intervals by one of the laboratory men, but one of the eggs went bad and as a result all died. How the embryos burst the shells is as yet unknown. To complete the series, further collections will have to be made during the months of June and August.

Sharks of three other species were taken and dissected; one 10 feet 10 inches in length was caught in Key West Harbor; careful measurements

and notes were taken, and it is hoped that further collections may be made. Two of these sharks have not yet been identified.

Numbers of the southern stingray, *Dasyatis hastata*, were taken, mainly at the Marquesas, but no early embryos were obtained. In this ray, as the writer has found to be the case in its near relative, *D. say*, the left ovary and left uterus only are functional.

Several species of bony fishes were collected, measured, weighed, dissected, and peculiarities of structure noted. Notes were also made on the contents of the digestive tract and on the condition of the reproductive organs.

Studies of Echini of Montego Bay, by Robert Tracy Jackson, Boston Society of Natural History.

Having recently been engaged on a study of recent and fossil echini, I was glad to have the privilege of joining the Carnegie Institution of Washington Expedition to Jamaica in order to extend my studies on certain species occurring in that region.

Centrechinus setosus (*Diadema setosum* auct.) is vastly abundant at Montego Bay. The adult is characterized by the fact that three oculars reach the periproct, or are insert, namely, I, V, IV, or the bivium and the left ocular of the trivium. While there is considerable variation (principally either I, V, IV, II, or all insert as progressive variants), I, V, IV insert is strongly the species' character. In young specimens up to 14 mm. in diameter all oculars are exsert and genital pores are entirely wanting. With later growth, as a developing feature, gradually oculars begin to travel in, reaching the periproct, and they do so in the sequence V, I, IV, or I, V, IV, the former order prevailing. With growth, perforations also soon appear in each of the genital plates. *Centrechinus* has a very slow, not a rapid or accelerated development as compared with more specialized echini, such as members of the family Echinidæ, and *Strongylocentrotus drobachiensis*. This is in complete accord with what Professor Hyatt has shown in fossil cephalopods, that primitive types with the same degree of growth have a much slower rate of development than specialized types. In young *Centrechinus* auricles of the perignathic girdle exist as slender separate styles, whereas in the adult these structures are broad and lamellar and arch over the ambulacra, meeting in a median suture. Apophyses also are very slight in the young, whereas in the adult they form quite high ridges. The structure of the teeth and dental capsules were observed in a number of genera.

Tripneustes esculentus is quite abundant at Montego Bay and attains a large size, but young specimens were infrequent. Of this species, material previously studied* shows a quite wide range of variation as to which oculars reach the periproct, but the variation with few exceptions is very definite. Omitting the exceptions for brevity, in adults ocular I alone may rarely be insert (8 cases seen in 1,133 specimens), or I, V; or I, V, IV; or I, V, IV, II; and finally all five oculars may be insert. This range was seen in series from a number of localities, but the typical character and the percentages of variants therefrom vary a good deal with different localities. In *Tripneustes* from Bermuda oculars I, V are insert as the typical local character. In Florida material, oculars I, V are still insert as the character, but with a lower percentage. In the Bahamas I, V insert occurs, but has passed into the phase of a common arrested variant, and I, V, IV insert is the typical local character.

* R. T. Jackson. Phylogeny of the Echini. Mem. Boston Soc. Nat. Hist., vol. 7, 1912.

At Montego Bay specimens with oculars I, V, also with I, V, IV insert, are common, but both have passed into the phase of arrested variants and oculars I, V, IV, II insert is the local typical feature. This is of interest as showing a progressively differentiated typical character in different localities. The variations in each locality cover practically the same range of characters, but the local character as regards oculars passes from a lower to a higher plane on a perfectly definite line of specialization. For all five oculars to be insert is a progressive variation in the species for all localities. While oculars I, V, IV, II insert exists as a progressive variation in a number of different species of recent echini, the occurrence of this feature as a dominant character in *Tripneustes esculentus* at Montego Bay is the only known case of its being a prevailing character in any living species.

The Spermatogenesis of the Mongoose of Jamaica, by H. E. Jordan, University of Virginia.

An effort was made to secure the maturation stages of *Echinaster crassispina*. The males were ripe in March, but no ripe eggs could be found in the apparently fully developed ovaries. At the time of our visit to Jamaica I was prosecuting a comparative study of mammalian spermatogenesis with special reference to the presence of an accessory chromosome. I was therefore fortunate in securing in Jamaica excellent material of the mongoose upon which to further extend the investigation. This was favorable for a complete study of spermatogenesis.

The mongoose, like the cat, squirrel, and pig, shows at no stage any indication of an accessory chromosome. On the contrary, in sheep, mouse, bull, mule, and horse such indication (or of a heterochromosome group) clearly appears at some stage (or stages) of the first spermatocytic prophase, including synapsis.*

The inference is strongly suggested that heterochromosomes are simply variously modified ordinary chromosomes, and that if their presence in the male has any connection with sex-determination this connection is not dependent upon a specific behavior dependent upon morphology. On the other hand it seems probable, in view of the presence of an accessory chromosome (double) in the egg of the cat, according to Winiwarter and Sainmont, that the element when absent in the male is present in the female. If the presence of an accessory or heterochromosome can be demonstrated, and confirmed by actual counts in oögonial and spermatogonial metaphase plates, in the growing oöcytes of squirrel, mongoose, pig, and similar forms, then the close causal connection between sex-determination and heterochromosomes will be more firmly established.

Material was collected also for a study of the embryology of the mongoose and of the anatomy of its adult brain.

The Dimorphic Spermatozoa in Marine Prosobranchs, by Edwin E. Reinke, Princeton University.

The main object of this investigation was to determine, if possible, whether the apyrene spermatozoa of *Strombus* play any part in the fertilization of the egg. Owing to the lack of ripe eggs of that species, no definite results were obtained. Ripe sea-urchin eggs were then tried, but they had no effect upon either kind of spermatozoa, except in a few instances where the egg-mem-

* I have already described an accessory chromosome in the opossum and in the bat.

brane had been ruptured. In such cases it was found that the eupyrene spermatozoa swarmed around the egg, while the apyrene remained unstimulated.

In February and March, in Jamaica, although the eggs of *Strombus* were not yet ripe nor the ovary fully developed, the seminal receptacle was found to be full of eupyrene spermatozoa, indicating that copulation had already taken place. When mixed with water the spermatozoa soon became very active. In no instances were any apyrene spermatozoa found in the seminal receptacle. Occasional clusters of granules resembling those of the adult apyrene spermatozoa were always present in the contents of the seminal receptacle, but these probably came from ruptured secretory cells which line its cavity.

The condition of the testis of *Strombus* was such that it was possible to study the developmental stages of the apyrene spermatozoa in the live condition. By so doing I was able to verify many figures that had been previously drawn from sections of preserved material.

In addition to *Strombus*, the dimorphic spermatozoa of *Turbinella, Triton,* and *Cassis* were examined and material collected for purposes of comparison.

Investigations on the Hybridization of Echinoids, by D. H. Tennent, Bryn Mawr College.

During the first half of my stay at Montego Bay I reinvestigated reciprocal *Hipponoë* and *Toxopneustes* crosses in order to ascertain whether the same types of larvæ were to be obtained in March as I had previously obtained at Tortugas in June and July, such observations being desirable because of those on seasonal variation made by Vernon and others. It may be said that, in general, the *Hipponoë* influence, although pronounced, was less strongly marked than in my previous experiments. A modification of skeletal structure was brought about by methods similar to those described in my article in Publication No. 132 of the Carnegie Institution of Washington, 1911. During the second half of my stay I obtained and studied material from other crosses.

I count myself especially fortunate in obtaining crosses between *Cidaris* female and *Hipponoë* male and *Toxopneustes* male. A study of the normal early development of *Cidaris* showed that, in this form, the mesenchyme is formed very late, being given off during the gastrula stage *from the inner end of the archenteron* about 26 hours after fertilization. In *Hipponoë* and *Toxopneustes* the mesenchyme is formed much earlier, arising before gastrulation about 8 hours after fertilization.

In the *Cidaris* female × *Hipponoë* male and *Cidaris* female × *Toxopneustes* male crosses, the mesenchyme is formed slightly earlier than in the straight development, the first mesenchyme cells appearing *at the lips of the blastopore* at the base of the archenteron. The observation gives very conclusive evidence of the early influence of the foreign sperm on development.

During my stay at Montego Bay I also obtained material for the following cytological studies:

(1) A further study of the *Hipponoë* female × *Toxopneustes* male cross.
(2) A further study of the same cross modified by the addition of N/10 acetic acid.
(3) A study of chemically fertilized *Hipponoë* eggs.
(4) A study of normally fertilized *Cidaris* eggs.

(5) A study of chemically fertilized *Cidaris* eggs.
(6) A study of the *Cidaris* female × *Toxopneustes* male cross.
(7) A study of the *Cidaris* female × *Hipponoë* male cross.

Through the kindness of Prof. R. T. Jackson, I have also a series of probable *Hipponoë* × *Toxopneustes* adult hybrids for study.

Studies of the Geology and of the Madreporaria of the Bahamas and of Southern Florida, by T. Wayland Vaughan, U. S. Geological Survey.

BAHAMA EXPEDITION.

The expedition to the Bahamas left Biscayne Bay, Florida, under Dr. Mayer's direction on April 28 and returned on May 27. The program for my work comprised (1) a study of the geology of the localities visited and of present geologic agencies in order to obtain a basis for the interpretation of the geologic history of the region; (2) a study of the Andros Barrier Reef and of the general ecology of the corals; (3) experimental investigations of the growth-rate and of variation of corals. Because of continued high winds the program could not be fulfilled in two particulars. It was not possible to do the dredging needed to ascertain the lower bathymetric limits of the shoal-water corals, and procure the collections necessary for a study of variation with increasing depth; nor was it possible to establish a coral plantation on the outer reef. In all other respects, however, the program was executed as planned.

Information on a number of subjects was gleaned in the field, considerable collections of bottom samples, rock specimens, and corals were made, and a large series of experiments and observations on the growth-rate and on the effect of environment on the variation of corals was initiated at the eastern end of South Bight, Andros Island. As this was a preliminary expedition and as the collections made have not yet received detailed laboratory study, it is at present possible to give only some general results.

Special attention was paid to the geology of New Providence and Andros islands, and North Cat and Gun cays were again examined. Although the rock specimens collected have not been studied in the laboratory, some conclusions reached in the field may be stated. New Providence Island is composed of a platform of oölitic limestone, similar to that found in southern Florida. The height of the platform ranges from sea-level to an elevation of about 20 feet. Rising above the "plains" are several ridges, the most important of which are the ridges south of the sea-front at Nassau and Blue Hills, south of Grantstown Plain.*

The height of Nassau Ridge is about 100 feet, while that of Blue Hills, according to my aneroid, is about 75 feet. The ridge at Nassau is evidently an eolian accumulation, as Mr. Agassiz has contended, but I doubt the eolian origin of the rock underlying the platform on which the ridge stands. More detailed information was obtained on Andros Island.

Andros Island is in reality a large group of islands. The area south of South Bight will be referred to as South Andros Island. These islands are composed of an extensive platform, ranging in elevation from sea-level to 20 feet or perhaps slightly more. The eastern front is higher than the western. Along the eastern side of South Andros Island and of Mangrove Cay are

* A. Agassiz gives a detailed description of the physiography of New Providence Island and a profile section in his "A reconnaissance of the Bahamas and of the elevated reefs of Cuba." Bull. Mus. Comp. Zool., vol. 26, 1894, pp. 18–24.

interrupted ridges or hills from 30 to 100 feet high. The rock at Driggs Hill, near Sharp Rock Point, is composed of oölite entirely to its summit, but the exposures examined were inadequate for forming a conclusion as to whether or no the rock is an eolian accumulation. Although the origin of the rock composing the ridges is in doubt, it can be positively stated that the rock underlying the general low-land, above which they stand, is a *marine oölite,* similar in all respects to that so abundant in southern Florida. This oölite extends through South Bight from the east to the west coast, and contains Pleistocene marine fossils at many localities. The bottom samples show that oölite forms the sea floor across the Great Bahama Bank throughout the entire distance between Gun Cay and Northwest Passage.

Both Gun and North Cat cays are largely composed of indurated, wave-tossed, detrital, calcareous sand, under which is an oölitic foundation.

It is evident that there are in the Bahamas three classes of material, viz, (1) extensive areas of marine oölite which form the great platform of Andros Island (or the Andros group of islands) and probably the platform of New Providence Island; (2) ridges and heaps of wind-blown calcareous material, Nassau Ridge being an instance of this kind of deposit; (3) wave-tossed and perhaps wind-shifted detrital material. More detailed investigations are needed to ascertain the extent of the areas underlain by each of these classes of deposits.

Several kinds of evidence bearing on oscillation were obtained on Andros Island. The marine fossils occurring at many localities above sea-level furnish proof of elevation. One of these localities, Sharp Rock Point (see map of Golding Cay entrance), will be specifically mentioned. This point, at northeast corner of South Andros Island, is composed of marine oölite. A short distance within it, between the "White House" shown on the map and the point of Sharp Rock Point, fossil corals, mostly *Mæandra strigosa,* occur embedded in the oölite, at an elevation of 5 or 6 feet above mean water-level. As many of the specimens appear to be in their natural growing position they indicate a slight elevation. Evidence of depression is afforded by submerged pot-holes. The present land surface of the oölite is rough, frequently almost devoid of soil except in pot-holes, locally known as "banana holes," because of the conditions they offer for the growing of banana plants. The depth of such pits may be as much as 10 feet. Submarine holes, known as "blue holes," are numerous in the vicinity of the eastern mouth of South Bight. Six of them, five off the eastern shore of Mangrove Cay, were examined in detail. Their depth ranges from 13 to 36 feet, while that of the surrounding water is 7 feet or less; their diameter may be as much as 200 feet, but is usually less, probably 20 to 40 feet. The largest hole examined, Blue Hole, north of Bastian Point (see map of Golding Cay entrance), has a diameter of about 200 feet and a maximum depth of 21 feet. These holes are undoubtedly submerged pot-holes and indicate a depression of at least 36 feet. Criteria are at present lacking for the positive determination of whether the last oscillation was upward or downward. It seems probable, however, that there was an elevation of perhaps 60 feet after the formation of the oölite platform, and that subsequently there has been a depression of at least 36 feet, but not sufficient to bring the marine deposits again below sea-level.

The geologic data collected, although fragmentary, are important, and will be of great value in making detailed plans for future investigations.

An attempt was made to dredge off the eastern shore of the north end of South Andros Island, opposite Sharp Rock Point, partly to obtain corals and

partly to ascertain the nature of the declivity on the western side of the trough of the Tongue of the Ocean. A heavy sea prevented accurate work, but it was discovered that a depth exceeding 100 fathoms is attained at a distance between one-quarter and one-third mile offshore (see map). The descent from the shore platform is very abrupt, if not actually precipitous, and the slope is hard and jagged.

Bottom samples were collected at intervals across the Great Bahama Bank from Gun Key to Northwest Passage into the Tongue of the Ocean, in Nassau Harbor, and through South Bight, from the east to the west side of Andros Island. Finely divided calcium-carbonate ooze or mud is of great extent in South Bight, where in places its depth exceeds 12.5 feet, and off the west side of Andros. This mud is precisely similar to that so abundant in southern Florida.* On the west side of Andros mud of this nature overlies the oölite and rises a few feet above sea-level.

The search to find öolite in process of formation by direct precipitation and segregation of particles in the sea was continued, but as no instance of such formation has so far been found, either in the Bahamas or in Florida, it appears that the oölitization of the limy muds must be due to a secondary process. (This subject is referred to in discussing the season's work in Florida; see page 157.)

The factors causing the disintegration and solution of coral skeletons (a special study of boring organisms was made by Dr. Paul Bartsch) and the effect of sand-feeding organisms on silt production were studied.

The barrier reef off the eastern shore of Andros was examined in the vicinity of the mouth of South Bight, from Long Bay Cays to Middle High Cay. South of Sharp Rock Point to Long Bay Cays the barrier reef is not continuous but patchy. These patches usually occur on the seaward margin of a short platform at a distance of three-quarters to a mile offshore. The depth of water on the platform ranges from 1 to 2 fathoms, while many of the reefs are awash at low tide. There is, on the seaward face of the reefs, a rapid drop to depths between 4 and 10 fathoms, and a depth of 50 fathoms is usually attained within a mile of the shore. North of South Bight, until near Middle High Cay, the same general relations of a shallow shore platform with reefs on its seaward margin obtain, but the reefs along this line are more nearly continuous, while within the outer reefs are some rather rich inner patches. Reefs also occur in the mouth of South Bight at both ends of Golding Cay and off Lisbon Point, and there is a shore reef between the tip of Sharp Rock Point and the lighthouse (see map).

On sheltered flats within the mouth of South Bight, as on the inner side of Forsyth Point, are corals, usually representing species different from those flourishing on the more exposed reefs. The field study gave an accurate idea of this part of the Andros Reef and of its general relations, and of the conditions under which the different species of corals live in the vicinity of South Bight. A considerable collection of corals, procured with particular reference to habitat, was made, and most of the species were listed in the field. The distribution of species according to habitat conforms to the principles found to govern their distribution in Florida. The outer reefs are characterized by such corals as *Orbicella annularis*, *Mæandra strigosa*. *M. labyrinthiformis*, *Siderastrea siderea*, *Agaricia agaricites*, *A. crassa*, *Acropora palmata*, *Porites astreoides*, and *P. clavaria* (form with short, stumpy branches). *Dendrogyra cylindrus* is also typically a reef coral. All these

* The mode of precipitation of this material is discussed by G. Harold Drew, pp. 143, 144 of this Year Book.

corals have a strong skeletal structure and either demand or thrive only in pure ocean water. The typical inner flat corals are *Mœandra areolata, Siderastrea radians, Porites clavaria* (form with more slender branches), and *P. furcata.* In areas more or less intermediate in character there may be some commingling of types. In the mouth of South Bight, where the inflow and outflow of water is strong, several reef-patches flourish, which have on them every species noted on the outer reefs except *Dendrogyra cylindrus,* while in these more protected places the more fragile branching species of *Acropora* especially flourish.

As has been stated, rough weather prevented planting corals or measuring colonies growing naturally on the outer reef; but a large plantation was established on the west side of the north end of Golding Cay at the point marked "1" foot in depth on the map, just under the word "Heads." At this place nearly all the species planted are living naturally, and a series of check measurements on specimens growing naturally was made. The specimens planted were weighed wet, then affixed to concrete disks with hydraulic cement and measured; the disk with the coral attached was weighed and photographed and then planted on an iron stake. The following plants were made:

List of corals planted on the west side of the north end of Golding Cay.

Name.	No. of disks.	No. of specimens.	Name.	No. of disks.	No. of specimens.
Dichocœnia stokesi	4	6	Siderastrea radians	3	4
Dendrogyra cylindrus	4	4	Agaricia agaricites	5	5
Orbicella annularis	6		Agaricia crassa and young indet. specimens	5	6
Orbicella cavernosa	1	1	Acropora muricata (= cervicornis)	14	14
Favia fragum	7	9	Acropora prolifera	8	8
Mæandra areolata	10	10	Acropora palmata	8	8
Mæandra labyrinthiformis	6	6	Porites clavaria	15	15
Mæandra strigosa	3	3	Porites sp.	1	1
Mæandra sp. not determined	4	4	Porites astreoides	6	6
Mussa (Isophyllia) dipsacea (perhaps includes some fragilis)	9	9	Total	129	135
Mussa (Isophyllia) rigida	5	5			
Siderastrea siderea	5	5			

This list includes at least 21 species, as usually understood, and perhaps one or two more. Eight of this number are not under observation at the Tortugas, while at that place the series for some of the others are deficient. In some instances the plants have been made to ascertain the effect of changed environment on variation.

The list of species of naturally attached specimens measured is as follows:

List of naturally attached corals measured for growth rate, off the west side of the north end of Golding Cay.

Name.	No. of measurements.	Name.	No. of measurements.
Dichocœnia stokesi	1	Siderastrea radians	2
Orbicella annularis	1	Siderastrea siderea	2
Orbicella cavernosa	1	Acropora palmata	2
Favia fragum	1	Porites clavaria	4
Mæandra labyrinthiformis	1	Porites astreoides	8
Mæandra strigosa	3	Porites sp. (young)	1
Mæandra clivosa	3	Total	36
Mussa (Isophyllia) dipsacea	2		
Mussa (Isophyllia) rigida	4		

The total number of growth records for this locality is 171.

FLORIDA STUDIES.

GEOLOGY AND GEOLOGIC PROCESSES.

While anchored in Biscayne Bay and during the cruise from Miami to Key West, the opportunity was used to examine many keys not previously inspected. These included Ragged Keys and Sands Key, Tea Table and Indian Key, and the smaller keys, Duck and Pigeon, between Key Vaca and Bahia Honda, all of which are largely composed of elevated coral-reef rock; elevated reef rock was also seen on Bahia Honda Key. The larger keys and some of the smaller ones between Big Pine Key and Key West are composed of Key West oölite. Summerland, Sugar Loaf, East Rockland, Rockland, Boca Chica, and Stock Island were examined and found to be composed of oölite. Most of the small keys north of the main keys and some of those to the south are mangrove keys. The Key West oölite, however, extends under the sea to the north of Key West and Stock Island. These data are in accord with those previously published on the kinds of rock forming the Florida keys.

During this cruise the mangroves of the regions were again studied, and important accumulations of mangrove peat noted at numerous localities.

The collection of bottom samples was continued, and specimens were obtained westward of Newfound Harbor Keys to Marquesas Keys. The attempt to find oölite in process of formation was continued, and although the material bearing on the problem has not yet been studied in detail, the following observations will be reported. It was stated in giving the account of the Bahama expedition that as the efforts to find oölite forming directly through precipitation and segregation of particles had negative results, it seemed necessary to attribute the oölitization of the calcareous precipitates to a secondary process.

Attention was then directed to discovering the process by which the rearrangement of the particles was effected. As it was surmised that the process might be associated with alternate wetting and drying, due to the rise and fall of the tides, specimens of mud were collected in Marquesas Lagoon and taken to Tortugas for observation and experiment. Although it appears that the effect of wetting and drying in converting the mud into oölite may be dismissed from serious consideration, observations, perhaps of importance, were made. The muddy bottom of this region gives off large quantities of gas in which H_2S is important, and it is present in all samples of mud. It was noticed that gas-bubbles* had formed in the samples that had been kept wet. The size of the bubbles varies greatly, but many range between 0.3 and 1.5 mm. in diameter, and remain embedded in the mud. Small particles of calcium carbonate collect around the peripheries of the bubbles and form crusts. These crusts simulate oölite crusts, in some instances several, two or three, concentric shells were observed. The interiors of the bubbles may be hollow, or there may be an included nucleus of a single grain or several grains of solid material. Furthermore, in some instances the included gas diffused outward through the surrounding crust without rupturing it, permitting a contraction of the coating without its losing its spheroidal or ovoid form. The matrix in which the incrusted bubbles are embedded varies in texture as the texture of the mud varies, which may be a putty-like paste, or contain a large or small proportion of fragmental material. The bubbles in some specimens were so numerous as to render the entire mass vesicular. Specimens illustrating the phenomena described

* This gas has not as yet been chemically analyzed.

were under observation at the Tortugas from June 28 to July 25, and several were brought to Washington and kept under observation until August 2, when I left for the remainder of the summer. On July 25 additional samples of mud were collected in Marquesas Lagoon and carried to Washington in tightly sealed Mason jars, so that they may be kept wet for a long period. Incrusted bubbles were numerous in this material soon after putting it into the jars.

It appears that oölite may be formed by calcareous crusts forming around embedded and confined gas-bubbles in the manner described. The large collection of bottom samples and geologic specimens have not yet been adequately studied, and until this has been done the observations on the incrustation of the gas-bubbles and their behavior under confinement are reported without attempting to make a wider theoretic application of the observed phenomena.*

[Observations on the samples of mud and the behavior of the confined, incrusted gas-bubbles have been continued subsequent to writing what precedes. It is probable that bubbles play only a small part in the rôle of oölitization, but the phenomenon of the attraction of particles may be fundamental. Additional studies are in progress. December 7, 1912.]

Besides the bottom deposits and the problem of the formation of oölite, other geologic processes were studied, among which may be mentioned the criteria for recognizing wave-built terraces and for recognizing cross-bedding due to wave-action, evidence of submarine solution in the Tortugas, and the effect of echinoids in producing silt. These subjects are a part of the general program for the study of geologic processes in the Florida region.

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* Although a general review of the oölite problem should not be given in this place, two important contributions to the subject by G. Linck may be cited, and two quotations introduced. The first of these papers, entitled "Die Bildung der Oolithe and Rogensteine (Neues Jahrb. für Min., Beilage Bd. 16, pp. 495–513, 1903), contains a statement of the theories on the formation of oölite and an account of some highly important experiments on the chemical precipitation of calcium carbonate and the crystalline form of the precipitates. Regarding spherulites of aragonite obtained in some of these precipitates Linck says (pp. 509, 510):

"Diese Sphärolithe sind nun nichts Anderes als die runden Körner der Oolithe und Rogensteine. Sie bilden sich auf anorganischen Wege als sphärische Concretionen mit oder ohne Kern, wo und wie sie es haben können. In litoralen Gebieten oder in der Nähe von Korallenriffen, wo die brandenden Wogen fortwährend Sandkörnchen, Bruchstückchen organogener Kalkmassen (Muscheln, Korallen, Foraminiferen, etc.) in flottirender Bewegung erhalten, lagern sich die Aragonit fasern um sie an; draussen auf offenem Meere oder in abgeschlossenen Seen bilden sie sich ohne Kern, oder die Einzelkryställchen von Aragonit (Algenstäbchen *Rothpletz*) dienen als solche, oder sie umschliessen organische Massen (Insecteier, Algen etc.) und auch Gasbläschen können von ihnen überkrustet werden."

In Linck's second paper, "Ueber Bildung der Oolithe und Rogensteine" (Jenaische Zeitsch., Bd. 54, pp. 267–278, Taf. 24, 25, 1909), is the statement (p. 276):

"Die Oolithe bestehen ursprünglich aus einer von Kalkspat abweichenden modification des Kohlensauren Kalkes (Aragonit), bei dessen Bildung organische Wesen nicht direckt beteiligt sind."

I am not prepared to discuss the rôle played by aragonite in the formation of oölite. However, certain facts regarding the origin of the Florida and Bahama oölites may be summarized:

Vaughan (A contribution to the geologic history of the Floridian Plateau, Carnegie Institution of Washington Pub. 133, pp. 135, 173–178, 1910) described deposits of chemically precipitated calcium carbonate in southern Florida and assigned a chemical origin to the Florida oölites.

Drew (Carnegie Institution of Washington Year Book, 1911, pp. 140–141) showed that denitrifying bacteria are important agents in producing this precipitation. His studies during 1912 were extended to the Bahama Islands (see this Year Book, pp. 136–144).

THE CORAL REEFS AND THE LIFE HISTORY OF CORALS.

The northern part of the Florida reef from New Cut, opposite Miami, to Pacific Reef, inclusive, both along the outer line of reefs and in the Hawk Channel, was studied. Some dredging was done from off Virginia Key to about a mile north of the jetty at the eastern end of New Cut. Some additional inspection of the reefs and the bottom in the vicinity of the Tortugas was made. The survey of the Tortugas area, however, is not yet complete.

Mr. George C. Short, U. S. Navy, of Fort Jefferson, according to an agreement, took readings of the temperature of the water at the wharf, in the moat, and at the west flood-gate of the moat at Fort Jefferson, twice a day from June 16, 1911, to June 16, 1912, furnishing a complete and an accurate record for these stations for the period covered. These data, when combined with other available information, will supply accurate information on the temperature of the surface waters of the Florida reef region.

Water samples for salinity determinations were taken at several stations in the Tortugas, and arrangements were made with Mr. Short to collect additional samples throughout the year in order to ascertain the variation in salinity.

Although the information on the physical conditions prevailing in the region of the Florida reef is still far from sufficient, additional data are gradually accumulating, justifying the expectation that it will not be a great while before these conditions will be adequately known.

Besides continuing general observations on the conditions under which the different species of corals live, special attention was devoted to three subjects, viz, (1) reactions to food and to non-nutrient particles and the nature of the food of corals; (2) endurance of atmospheric exposure; (3) growth-rate. As it is intended to present a detailed account of the results of the last five years' studies of the Tortugas corals in a forthcoming volume of "Researches from the Tortugas Laboratory," the researches of 1912 need be only briefly described in this place.

The reactions to food and to non-nutrient particles were studied in detail in *Mæandra areolata* and in more or less detail in 15 other species. Previously the subject had received very little attention. *Mæandra areolata* was selected as the most suitable species for the preliminary detailed study because of the rather large size of the polyps of the colonies and the ease of obtaining abundant specimens. The mechanisms for capturing food and for ridding its surface of non-nutrient particles were first studied.

These mechanisms may be briefly described. (1) The entire ectodermal surface is beset with nematocysts, which occur on the tentacles, the oral disk, the column wall, including its downward extension, called the edge-zone, and also on the margins of the mesenterial filaments. The nature of these organs is too well known to require description in these remarks. (2) The entire ectodermal surface is ciliate, the cilia in response to certain stimuli beating toward the oral apertures; in response to others, beating toward the periphery. (3) The outer surface secretes mucus in which particles may be embedded, the mucus moving under the influence of the beat of the cilia toward the oral apertures or toward the periphery, according to the nature of the response to the stimulation. (4) The tentacles are active and effective in capturing food. (5) The mesenterial filaments, which in many species of corals can be extruded through the column walls, in some instances capture food; these organs, however, do not seem to play an important rôle in *Mæandra areolata*.

The cilia of *Mæandra areolata,* external to a line corresponding nearly with the top of the septal arch, appear, as a rule, to beat outward, while those within this line appear usually to beat inward. The entire ciliary apparatus, however, may be made to operate in directions almost at the will of the experimenter. By stimulating the specimen with food the cilia from the lowest margin of the edge-zone may be made to drive the food toward the mouths, while if sand grains are used the cilia of the oral disk will drive the undesirable material toward the periphery.

In conducting the experiments to ascertain the responses to food stimuli, both solid and liquid food was used. The solid food consisted of bits of crab-meat (*Ocypoda arenaria*) or bits of minnows, and the liquid food of beef-juice. The reactions to these substances were in some particulars similar, in others different. The specimens to be experimented with were placed in glass dishes, deep enough to submerge the specimen to a depth of half an inch or more, and the experiments were conducted on a well-lighted shelf or table, but not in direct sunlight.

When a piece of solid food is placed on the oral disk of a specimen, under the conditions indicated, the polyps begin immediately to distend, the stimulus passing from polyp to polyp, and if the specimens be not too large the entire colony will expand. Very nearly any specimen of coral may be induced to expand in ordinary shaded light, shielded from direct sunlight, by placing a piece of solid food on its surface. (I have seen a specimen of *Mæandra clivosa* in its natural habitat, with its polyps fully distended in strong sunlight.) When a piece of solid food is offered to a tentacle it is seized and passed downward to a mouth which opens to receive it. Then the upper edges of the edge-zone are brought together, forming an arch over the mouth. After the food particle has been completely swallowed the edge-zone margins usually separate, exposing the oral surface. An experiment, repeated several times, was to place a piece of *Ocypoda* meat in a depression on the top of a colline, in the most inaccessible place on the upper surface of the specimen. All tentacles near the bit of food were directed toward it, and it soon moved upward over the septal arch and was captured by a tentacle. Through the combined action of the cilia and mucus, food particles can be carried to a mouth from any part of the outer surface of the soft tissues.

Carmine particles were mixed with the beef-juice when using this material in experiments. The function and operation of the cilia and mucus are the same in response to the stimulation of liquid food as to that of solid food, but the tentacles usually remain inactive. The mucus with the entangled carmine grains moved toward the mouths, in some instances being drawn as colored streamers into the mouths, which open very widely. Occasionally a tentacle may grasp a mucus thread, while sometimes the tentacles may be entirely retracted. After the liquid food is within the margins of the edge-zone, the edges contract over the oral apertures and, after the swallowing is complete, retreat, exposing the oral disk.

After satiation the direction of the ciliary motion reverses, so that what was taken as food is carried to the periphery and dropped off, and the tentacles will not seize food particles.

The preceding remarks give a summary of the principal reactions to food of *Mæandra areolata.* In other species, one of which is *Orbicella cavernosa,* the mesenterial filaments can, while protruded through the column wall, not only catch food, but can digest the food without taking it into the gastric cavity.

All the 16 species of corals investigated with reference to ridding their surface of non-nutrient particles can clean their surfaces. Fine sand grains were used in making the experiments. Some of the sand which may fall near a mouth may at first be swallowed, but soon it will be ejected and the cilia will beat outward, moving the grains, embedded in mucus, toward the periphery. The capacity of corals for cleaning themselves varies from species to species. The special adaptation for withstanding considerable quantities of silt can here only be mentioned. One of them is the capacity through the combined action of the mucus and cilia to remove silt from their surfaces; another is by having a branching growth form to present no flat surface on which silt may settle.

Numerous observations and experiments were made to ascertain the nature of the food of corals. While at Golding Cay, Bahamas, Dr. Mayer called my attention to some of the corals kept in a live-car, and also to some in a state of nature, catching and holding specimens of the small jelly-fish (*Linuche*). Subsequently, I saw other instances of similar capture of *Linuche*. *Dendrogyra cylindrus, Mœandra clivosa,* and *Siderastrea sidera* were the corals observed that had caught jelly-fish. I have seen a specimen of *Mœandra areolata* that had caught a small crab, and it digested all the soft parts of the crab. That corals will eat a variety of cut-up animal sea-food, crustacea, and fish, my feeding experiments proved, and *Mœandra areolata* will eat pieces of the flesh of its own species. Plankton tows were made and the plankton fed to the corals. *Mœandra areolata* took copepods, amphipods, crab zoea, *Sagitta, Salpa domestica,* young fish, etc.; every kind of visible animal plankton except pycnogonids. The surety and rapidity with which the tentacles worked in catching living copepods was astounding. Of a number of copepods dropped with a pipette within the rows of tentacles not one escaped. Not only did the tentacles catch copepods, but specimens of these small crustacea dropped on the edge-zone, outside the tentacles, were caught, entangled in mucus, and carried to the mouths. The experiment was tried four times, each time with the same result. Animal plankton was fed to other species and was generally taken.

Feeding diatoms and chopped-up sea-weeds was tried. The diatoms were obtained from cultures made in the laboratory, as this method gave an abundance of these organisms with only a small admixture of other kinds. Not a coral experimented with would take pure diatoms as food, but would take them if they had been soaked in meat-juice. The following experiment was tried many times: First, a piece of diatom mat was placed on one side of a calice; then a bit of *Ocypoda* flesh was placed on the other. Invariably the *Ocypoda* meat was seized and swallowed, while the diatoms induced no reaction, except ultimately to be removed from the surface. No kind of purely plant food was taken by any one of the numerous species investigated. However, pieces of plants coated with small animals or soaked in meat juice will be swallowed, and later the vegetal matter ejected. The food of corals consists solely of animal matter.

This brief summary indicates the mechanisms of corals for catching food, that for keeping their surfaces clean, and the nature of the food of corals. The details of the investigation will be published later.

Experiments were made on 16 species of Tortugas corals to ascertain the amount of atmospheric exposure they would endure in the shade and in the sun. The details of these experiments will be given in a subsequent publication. Here it will be stated that any of the Tortugas shallow-water spe-

cies of corals will endure atmospheric exposure on a glass plate in the shade for half an hour without apparent damage; nearly all will stand an hour without harm, while some will stand 4 hours' exposure under the conditions stated. *Favia fragum, Porites clavaria,* and *P. astreoides* have the greatest capacity for withstanding atmospheric exposure, while that of *Mæandra areolata* and *Siderastrea radians* is almost as great. A number of species withstood exposure on a glass plate in the sun for 1½ hours, the specimens being badly damaged, but not entirely killed.

The studies of growth-rate were continued in 1912 as in 1911. There are under observation (1) colonies reared from planulæ that settled in the aquarium; (2) colonies from planulæ that attached themselves to collectors; (3) specimens cemented to tiles; (4) colonies growing naturally at one of four stations. No detailed statement of these experiments and observations has been made, except accounts of the rearing experiments, tables giving the size of the yearling colonies, and three plates illustrating a few planted corals, have been published in the Year Books of this Institution. As there are many hundred growth records, it is not possible to present them here, but they will be published in the next series of papers from the Tortugas Laboratory, and a summary of the results to date will be given. The experiments have been very successful and will furnish accurate information on the growth-rate of nearly all the species of corals found in the Florida reef region.

Report on the Limits of the Spectrum for Birds, by John B. Watson, of Johns Hopkins University.

While at Tortugas I began a study of the limits of the spectrum in day birds. This work was begun primarily for the purpose of testing the theory which has been advanced often to explain the homing sense. Certain French investigators assume without experimental proof that homing birds use for orientation rays in the spectrum which lie in the infra red. They assume further that since these rays (heat rays) follow the curvature of the earth, the birds without rising to extraordinary heights may directly perceive the goal (côte, nesting locality, etc.). While this theory seems more or less absurd upon its face, it deserves at least an experimental test. Entirely apart from its bearing upon the homing sense, data upon the visible spectrum of animals are much needed in comparative psychology and in sensory physiology.

A large spectrometer was constructed, which enabled the experimenter to select any monochromatic bundle at will. The selected spectral band was allowed to fall upon a plaster surface.

The birds were tested in an experimental cage, as follows:

A home box gave entrance to two compartments. These two compartments were separated by a partition. Each compartment contained a plaster-paris surface for the reception of the light. Only one compartment was illuminated in any one test. The animal when released from the home box might choose either the lighted compartment or the dark one. It was fed if it chose the lighted compartment, but was not fed if it chose the dark one. The apparatus was so arranged that the lighted compartment could be offered either on the right or left side. It is clear that after an animal has been trained in this way it will continue to respond as long as the plaster-paris surface is illuminated by rays which affect the receptor.

Since the work on homing at the Tortugas laboratory has been carried out upon the noddy and sooty terns, it was attempted to make the first tests upon these birds. On account of the failure of the electric light plant to give a current sufficiently uniform to run the source (Nernst filament), the work was abandoned in Tortugas. Twenty-four birds were taken back by rail to Baltimore, but all of them died before experiments could be completed. The work was continued in Baltimore upon chicks with interesting results.

In the first place, the chicks chose the lighted compartment from the first—they are positive to light. Experiments were begun with green $\lambda = 5480$ and were then continued with red. At the beginning of each day's set of experiments the length of wave was increased. It became evident after several days' experimentation that there is enough diffuse white light admitted by any single spectrometer system to cause a response on the part of the animal, entirely apart from the presence of the monochromatic light. This difficulty was avoided by putting a filter behind the selecting slit of the spectrometer, which admitted 80 per cent of the light from $\lambda = 700$ to $1\ \mu$, but which excluded all shorter rays. Under these conditions the red limit for the chicks under observation was found to be $\lambda = 7110$.

In order to obtain the violet limit the arc light was substituted for the Nernst. This light is intense in the violet and ultra-violet. Filters for excluding the diffuse white light were again found necessary. The violet limit was found to be approximately $\lambda = 3950$.

These results are not in harmony with those communicated by Hess. He holds that the chick is blind to blue and violet. His method of making the test was very crude and involved visual acuity (*i. e.*, his animals had to pick up small (rice) grains illuminated by monochromatic light).

The experiment is being carried further in a slightly modified apparatus. Instead of using filters for the exclusion of white light a second spectrometer is employed. The selecting slit of the first spectrometer becomes the source for a second spectrometer (purified spectrum of Helmholtz). The selecting slit of this second spectrometer admits a monochromatic band wholly free from white light. In this more careful set of experiments the different bands of light are equated in energy by means of the selenium cell.

In addition to testing the limits of the spectrum, the sensitivity curve for monochromatic light in chickens and in homing pigeons is being worked out, *i. e.*, the threshold at the various points in the spectrum is obtained in terms of comparative energy values.

Note upon the Audibility of Sounds Produced under Water, by John B. Watson, of Johns Hopkins University.

Parker ("Effects of explosive sounds, such as those produced by motor-boats and guns, upon fishes," Bureau of Fisheries Document No. 752) finds that the noise of motor-boats is extremely faint under water and has almost no influence upon the movements of fishes engaged in feeding. The single explosive sounds like that of the report of a gun are likely to startle the fish and cause a temporary cessation of feeding.

Some tests made by Dr. A. G. Mayer, Dr. Goldfarb, and the reviewer in Tortugas during the past summer on the distance at which sounds produced under water may be detected by a person with head and body immersed do not bear out Dr. Parker's contention that sounds heard under water are extremely faint. Dr. Mayer tapped two pieces of coral together under water

while Dr. Goldfarb and the reviewer swam away. Up to a distance of approximately 100 yards the faint sounds made in the above manner were distinctly heard by both observers with head and body immersed. At this distance Dr. Mayer tapped the two pieces of coral together in the air. They were clearly audible to the observer with head in the air, but unfortunately we did not try the experiment of giving the sound in the air with the observers' heads immersed.

In Dr. Parker's work no mention is made of the possibility of vision being responsible even for the slight responses he obtained. In the opening sentences of his present paper he says that the fish can feel sounds through the *skin, lateral line organs,* and through the ears proper. One of the strong criticisms urged against all of Parker's auditory work by certain German reviewers is that he does not exclude the possibility of response through vision (*i. e.,* visual response to actual wave-motions produced by the sounding body). In the present paper, although he cites the work of Hunter (1782) on the responses of fishes to the noise produced by the discharge of fowling-pieces, he does not consider the work of Bernoulli (Zur Frage des Hoerenvermoegens der Fische, Arch. f. d. ges. Physiol. CXXXIV, 633–644; see review of 1910 literature in Journal of Animal Behavior, vol. I, p. 436), who made similar experiments and arrived at similar conclusions.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

LEWIS BOSS, DIRECTOR.

The period covered by this report extends from September 1911 to September 1912.

OBSERVATIONS.

The transit circle has been remounted. The instrumental tests applied show that there is no appreciable change in the instrument, such as might be caused by rough handling on its return trip from the southern station at San Luis, Argentina.

After the completion of the preliminary tests and final adjusting, observation was commenced on November 13, 1911. While the past year has been very unfavorable for observation, because of the excessive cloudiness, 9,715 observations have been taken, distributed as follows: A. J. Roy 4,703, B. Boss 2,545, and W. B. Varnum 2,467. Because of continuous clouds, not an observation was taken from December 29, 1911, to February 15, 1912. The same plan has been adhered to, of having each observer on duty continuously for a week.

The process of observing a group of stars in the afternoon and again in the morning, in addition to the night observations, has been continued; and when possible successive transits of polar stars above and below pole have been taken for an independent determination of the azimuth of the instrument.

In addition to the fundamental observations, the above summary includes the observations of miscellaneous stars chosen in accordance with the program already outlined for this Department.

The usual determinations of magnitude-equation, of difference of transit North *minus* South, of Chronograph *minus* Eye and Ear, etc., have been included.

In all the observations, circle *B* (opposite the clamp) was read, the distribution thus far being BE 4333, BW 5382. Four microscopes have been recorded at each setting, the distribution of readings being as follows: H. Raymond 4,744, S. B. Grant 4,528, and H. Jenkins 421.

COMPUTATIONS UPON OBSERVATIONS.

The computations have been mainly concerned with the reduction of the observations taken at San Luis, Argentina.

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* Address Dudley Observatory, Albany, New York. Grant No. 747. $26,316 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 2–10.)

The remainder of the reductions from apparent to mean place have been finished, and all the corrections entered upon the duplicate sets of right-ascension sheets. The pivot corrections have been entered for both sets of computations. Definitive collimations have been determined for the San Luis observations, and these collimations have been entered on one set of right-ascension sheets as far as series 398. For the definitive determination of the collimation it has been assumed that the collimation is constant over a considerable period of time (not including the change due to temperature), and that such a constant more truly represents the actual collimation than the individual determinations. On this assumption the probable error of a single determination amounts to $\pm^s.012$, the collimation in general exhibiting an excellent agreement. The temperature coefficient was found to be $-^s.005$ clamp *E* at $+15°$ C. The temperature used is that of the thermometer attached to the barometer. It has previously been found that there is a lag in instrumental constants, and as the barometer is inclosed in a case, the lag of the change in temperature in the barometer case seems to somewhat approximate the lag in the collimation.

The level constant, determined from nadir readings, generally represents a smooth curve for any one series of observations. Although there is evidently a mean effect of temperature on the level, it can not be employed because of the many anomalous series.

The correction for the effect feet north or south and that for the correction of Eye and Ear *minus* Chronograph have been applied to both sets of right-ascension sheets.

Nothing has been done as regards the application of the magnitude equation, as we are awaiting the magnitudes now being determined at San Luis before entering these corrections.

AZIMUTH AND CLOCK CORRECTIONS.

A considerable portion of the efforts of the staff of the Department of Meridian Astrometry during the past year has been devoted to an independent derivation from the transits of the San Luis observations of clock correction and azimuth, so far as it could be carried at the present time. After correction of the transits for personal equation for magnitude, pivot correction, collimation, and level, the azimuths were derived from transits, at successive upper and lower culminations, of stars within 13° of the South Pole. The list of azimuth stars included 17 of this description. Each fundamental observer was on duty for one week and results for one culmination were combined with transits by the same observer.

In reducing the observations, differential corrections were applied to a given transit of a circumpolar star from one culmination to another, preceding or following by 12 hours, so that the azimuths are independent of any adopted right ascension of the circumpolar stars. In order to establish a period within which the instrumental azimuth could be regarded as fixed, it

was assumed that the zero azimuth was constant for each week assigned to one of the given fundamental observers, R. H. Tucker, A. J. Roy, and W. B. Varnum. It was found that the mire reading remained sensibly constant during each week, but that it varied periodically during each 24 hours. This periodic variation was assumed to change with the azimuth of the instrument, and that change is probably due to diurnal variation in the relation of the instrumental piers of the transit-circle and its parts, so that the results of successive transits of circumpolar stars could be made comparable by differential corrections. Each double transit by the same observer, in connection with the mire reading, furnished an individual value of the azimuth of the instrument, and in connection with the differential corrections applied to the transits of clock stars led to the independent right ascensions of the circumpolar stars. Both azimuths and right ascensions proved to be quite consistent with the assumption made.

The results for individual azimuths were carefully plotted and curves drawn to connect these together. These curves were read off at intervals of an hour and exhibited a close similarity throughout, save that they showed small seasonal changes in the weekly constants.

The mean systematic difference between independent right ascensions for the 17 fundamental circumpolars (Obsd.–P. G. C.) appears to be relatively small. It is:

$$+^{s}_{.}025 \sec \delta.$$

When these right ascensions were subsequently expanded to include 50 circumpolar stars, all based on independent azimuths, this became

$$(\text{Obsd.} - \text{P. G. C.}) = +^{s}_{.}027 \sec \delta.$$

For the 17 stars, the probable error of a single right ascension is $\pm^{s}_{.}020 \sec \delta$, while for the miscellaneous circumpolar stars making up the 50 the corresponding probable error equals

$$\pm^{s}_{.}023 \sec \delta.$$

In all the preliminary operations clock stars were chosen between $+30°$ and $-30°$ in declination, preferably between $+30°$ and $-20°$. The clock-rates were determined from groups between these limits of declination, 24 hours apart, corrected the second group to the first, for change in azimuth, usually small, as well as for collimation, level, etc., in a manner analogous to the treatment of circumpolar right ascensions. The right ascensions of the 217 clock stars selected from the Preliminary General Catalogue show small differences, depending on the declination, in the observed right ascensions compared with those of the Preliminary General Catalogue between the limits of $+30°$ and $-20°$ of declination.

From the azimuth curves previously mentioned clock corrections have been computed. These clock corrections were then arranged in 12-hour groups to free them from systematic error dependent upon right ascension.

These groups afforded the material for the determination of both the effect night minus day, and the term dependent on right ascension. The results from the normal equations follow:

$$-{}^{s}.0084 \sin \alpha + {}^{s}.0087 \cos \alpha.$$

Observer.	N — D.
	s
R. H. Tucker	— .010
A. J. Roy	+ .007
W. B. Varnum	— .016

Applying these results to the observed clock corrections, clock-rates were computed by the formula $\Delta T = C + xt + yt^2$. The rates thus obtained fit the observed clock corrections with a mean probable error of $\pm {}^{s}.032$.

These clock corrections are now being applied to all the fundamental stars, to furnish tests.

REDUCTION OF DECLINATIONS.

During the past year much labor has been expended upon this branch of the San Luis reductions, but we have not yet reached the final stages.

For the duplicate series of zenith-distance sheets there have been entered to date the curvature, correction for inclination, correction for flexure, refraction, reduction from apparent to mean place, division correction, and feet South *minus* North.

The mean places of the fundamental stars as determined from the Preliminary General Catalogue have been entered for about half the series on one set of zenith-distance sheets.

A redetermination of the circle flexure at Albany in November 1911 showed little change in this quantity, and what change there is most probably can be attributed to its indetermination. Three determinations of circle flexure give—

		Circle A.		Circle B.	
Albany,	1905	$-{}''.51 \sin t$	$-{}''.34 \cos t$	$-{}''.45 \sin t$	${}''.63 \cos t$
San Luis,	1909	— .51	— .31	— .65	.59
Albany,	1911	— .65	— .31	— .44	.60

For the telescope flexure the following results have been obtained:

Telescope Flexure.

Albany, 1908	$+1{}''.11$
San Luis, 1909	+0.98
San Luis, 1911	+1.11
Albany, 1911	+0.98

Three determinations of the division corrections give:

DIVISION-CORRECTION.

Circle reading.	Corrections of Circle A.			Corrections of Circle B.		
	Albany.	San Luis	Albany	Albany.	San Luis.	Albany.
	"	"	"	"	"	"
15	+.11	+.08	−.01	−.91	−.96	−.94
30	+.22	+.28	+.26	−.09	+.01	−.14
45	+.23	+.25	+.32	.00	−.04	−.07
60	−.65	−.56	−.51	−.55	−.50	−.59
75	+.08	+.06	+.02	−.11	−.11	−.22

In the annual report of this Department for 1909 some of these values were, by inadvertence, miscopied.

The close agreement of these determinations of errors of graduation, together with the agreement of the circle flexure, is sufficient proof that the circles were unharmed in transportation to and from San Luis.

The eccentricity has been determined for the San Luis reductions and again when the instrument was set up at Albany, and the resulting corrections applied to the individual graduations in tabular form.

The corrections to be applied to north zenith-distances because of the effect depending upon whether the observer faces north or south have been determined and applied for the San Luis reductions.

Corrections to zenith-distance observed feet north.

Observer.	AE. and BW.	BE. and AW.
	"	"
R. H. Tucker	+.32	−.32
A. J. Roy	+.65	−.65
W. B. Varnum	−.12	+.12
M. L. Zimmer	+.28	−.28
R. F. Sanford	.00	.00

PHOTOMETRIC OBSERVATIONS AT SAN LUIS.

As has already been stated, the object of the photometric expedition to San Luis has been the determination of the magnitudes of all those stars on our meridian-circle program not determined elsewhere. For this work a wedge-photometer has been used. In spite of the criticisms of this form of photometer, the preliminary reductions would seem to indicate a degree of accuracy comparable with that obtained from other forms of photometers.

The photometric observing list has been finished from 4^h right ascension to $16^h\ 15^m$, according to the report received from San Luis (August 6, 1912). From 0^h to 4^h the list is almost finished and from $16^h\ 15^m$ to $18^h\ 50^m$ it is about half finished. About 13,500 observations have been taken of stars of undetermined magnitude, and about 1,500 more observations have been taken on fundamental stars for scale value, etc.

The weather conditions at San Luis during the last year have been trying, an almost unprecedented amount of cloudiness being recorded—quite a dif-

ferent state of affairs from that encountered by the meridian observers. Consequently the program has constantly been in jeopardy. Some observations have been taken on bright moonlight nights, or before it was entirely dark, more or less as an experiment. These observations will not be used unless they accord well with the well-determined magnitudes. The indications thus far seem to indicate that the illumination of the sky has but very little effect, as it seems to offset the star and the artificial light in the same way.

A rough comparison of the difference between two observations according to the preliminary reductions shows a mean difference between two observations of $0^{M}.16$. The final reduction may decrease this.

Mr. Meade L. Zimmer has continued in charge of the expedition.

On November 19, 1911, Mr. William Hunt, who had accompanied the expedition to San Luis as assistant, was accidentally drowned. Not only was his sudden death a great shock to us, but we felt that we had lost a very promising astronomer.

Mr. Heroy Jenkins sailed on January 4, 1912, to fill the position left vacant by Mr. Hunt's death.

From present indications it is probable that the photometric expedition will terminate early in 1913.

STUDIES UPON STELLAR MOTION.

The investigations upon stellar motions have continued during the last year. A group of stars moving at the high true velocity of about 80 km. per second has been discovered (Astronomical Journal, 629, 633–634), moving toward a convergent at right ascension $= 99° \ 9,'$ declination $= +0°.5$. Other investigators have added members to this group. The group motion is directed toward a point only about 7° distant from the vertex of preferential motion. The peculiarity of this group is that it contains stars from every quarter of the sky. Most of the stars in this group belong to the later types.

A very interesting investigation (Astronomical Journal, 635–636) was made of the proper motions of the stars arranged according to type. Some of the most important results of this investigation are:

(1) The tracing of group motion to the B-type stars.

(2) The visible effects of preferential motion practically originate and end in the A-type stars, accounting for the rapid acceleration of the motions of the A stars which is not continued in later types.

(3) In addition to the so-called preferential motion of Kapteyn, there are other tendencies of motion of the stars.

(4) With increase of galactic latitude there is an increase in the amount of acceleration between groups of A stars representing the preferential motions.

(5) Almost the reverse is true of the F type, seeming to indicate that the development of the star's acceleration in or near the galactic plane is slow, not fully maturing until the F type, whereas in higher galactic latitudes the A stars lose their preferential acceleration on passing from the A type to the F type.

(6) Passing to the K-type stars, very little resemblance to the early motions is left. The motions begin to approximate random motion.

(7) The effects of the Galaxy are traced even to high latitudes.

In Astronomical Journal, 632, H. Raymond has published tables giving the mean value of radial cross-motions, on the ellipsoidal theory advanced by Schwarzschild, for the areas used by the Director in his discussion of stellar motions.

FIREPROOF VAULT.

The necessity has long been felt for a fireproof vault in which to store the records and the card catalogue. The Executive Committee of the Carnegie Institution of Washington authorized the erection of such a vault out of the funds of the Department and the vault is nearing completion.

THE STAFF.

During the indisposition of the Director, Benjamin Boss officiated as acting Director.

The San Luis reductions of zenith-distance have been in charge of Arthur J. Roy, and the right ascensions in charge of W. B. Varnum.

H. Raymond has been variously employed upon responsible portions of the work.

Meade L. Zimmer is in charge of the photometric station in San Luis, assisted by Heroy Jenkins.

The staff has undergone slight changes during the year. As has already been mentioned, Mr. William Hunt died at San Luis November 19, 1911, through drowning. Mr. L. Z. Mearns resigned from the Department November 1, 1911. Mr. S. B. Grant was appointed November 13, 1911, to fill the vacancy caused by the resignation of Mr. Mearns, but as yet the place left vacant by the death of Mr. Hunt has not been filled.

In addition, the staff includes seven computers and a varying number of piecework computers.

MOUNT WILSON SOLAR OBSERVATORY.*

George E. Hale, Director.

The year has been one of minimum sun-spot activity, but good progress has been made in certain fields of solar research, and other departments of the Observatory's work have advanced in a very satisfactory manner. The completion of the new tower telescope and the addition of important auxiliary apparatus to the equipment of the 60-inch reflector have greatly increased our instrumental resources, while the erection of a fireproof office building in Pasadena will add to the efficiency of the staff and the safety of plates and records.

The Observatory has profited more than in any previous year from co-operation with eminent astronomers, who have come to Mount Wilson to conduct investigations for which our instruments are especially fitted. The advantages of our alliance with Professor Kapteyn become increasingly evident. With his counsel, the observing program of the 60-inch reflector has been planned so as to yield a maximum return, advantageous alike to the problems of stellar distribution and stellar development.

Among the results of the year's work the following may be mentioned:

(1) The 150-foot tower telescope and combined spectrograph and spectroheliograph have been thoroughly tested and found to be very efficient.

(2) The plane grating has been shown to be fully equal, if not superior, to the concave grating for the determination of the wave-lengths of standard lines.

(3) A difference in altitude of 5,100 feet (1,555 m.), corresponding to a difference in pressure of about one-fifth of an atmosphere, is sufficient to produce easily measurable displacements of certain lines selected for international use as tertiary standards, which should therefore be rejected.

(4) Except in a single instance, the wave-lengths of the international secondary standards are found to be of the highest accuracy.

(5) Certain iron lines are greatly displaced to the violet by pressure.

(6) A continuation of the investigation on the radial flow of vapors in sun-spots gives the following velocities: Calcium (H and K) 1.9 km. per second inward; hydrogen ($H\alpha$) 1.5 km. inward; sodium (D_1 and D_2) 0.2 km. inward; magnesium (b_1 and b_2) 0.4 km. inward; aluminum (λ 3961) 0.0 km. Various low-level iron lines show outward flow, with velocities ranging from 0.49 to 0.90 km. per second.

(7) A theoretical investigation has been made on the nature of magnetic fields produced under conditions similar to those existing in sun-spots.

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* Situated on Mount Wilson, California. Grant No. 749. $254,075 for construction, investigations, and maintenance during 1912. (For previous reports see Year Books Nos. 3–10.)

(8) An attempt to detect the Zeeman effect caused by the general magnetic field of the sun gives promising results.

(9) A working hypothesis of sun-spots has been developed as a guide to further research.

(10) A new and more accurate determination has been made of the correction to observed magnitudes which depends upon the distances of stars from the axis of the 60-inch reflector.

(11) An independent determination of the magnitude scale of the North Polar Sequence gives results in excellent agreement with those of Pickering from magnitude 10.5 to 15.5. For fainter stars there is some divergence, which is still under investigation.

(12) Photographs of the Algol variable *RR Draconis* show this star to be of unusual interest because of its great range of variation, which extends from magnitude 9.70 to 13.50.

(13) Visual and photographic observations of Mars, made with the 60-inch reflector, give no evidence of the existence of a geometrical system of straight "canals."

(14) About 850 photographs of stellar spectra, taken with the Cassegrain spectrograph, have yielded the radial velocities of about 250 stars.

(15) About 45 new spectroscopic binaries have been discovered, and many other suspected cases are under observation.

(16) The star *Lalande* 15290 has been found to have the largest apparently constant radial velocity hitherto observed (—248 km. per second).

(17) A study of the remarkable new star in *Gemini* indicates a constant radial velocity of about +10 km. per second, a marked resemblance of its spectrum to that of certain *Wolf-Rayet* stars, the probable presence of the nitrogen lines, and no marked evidence of radium. The star passed through the series of changes characteristic of *Nova*.

(18) A classification of 453 stellar spectra, based upon about 1,500 spectrograms obtained with the 60-inch reflector, gives results in good agreement with the Harvard classification. Some interesting new subdivisions have been found.

(19) Stars with strong enhanced lines seem to have a greater absolute luminosity than those in which these lines are fainter.

(20) In eleven cases of composite spectra belonging to spectroscopic binaries, the spectrum of the brighter component is always of the earlier type.

(21) Photographs of the integrated spectrum of certain regions of the Milky Way indicate that the greater part of its light probably comes from solar stars.

(22) A new determination has been made of the velocities of the helium stars of Stream I and the A stars of Streams I and II, and the positions of the vertices have been greatly improved.

(23) Certain helium stars have been found which apparently belong to Stream II.

(24) The extent and elements of the *Scorpius-Centaurus* and *Perseus* groups have been investigated, and parallaxes have been derived for stars in these groups having a sensible proper-motion.

(25) A preliminary investigation has been made on the distances from our system attained by the star-streams.

(26) It has been found that a number of stars in *Vela* probably form a local group.

(27) All local groups of stars, for which the necessary data are available, have been shown to move in space nearly parallel to the Milky Way.

(28) It appears to be true that the more distant stars are redder than the nearer ones, either because of absorption of light in space or through an influence of the absolute luminosity.

(29) Photographs of the very short spectra of faint stars, obtained with a large grating attached to the 60-inch reflector, afford a means of determining their effective wave-length, which is a measure of their color.

(30) A continuation of the investigation of the effect of pressure on furnace spectra confirms the results obtained last year and shows that variations in temperature and certain changes in the physical and chemical condition of the vapors are without appreciable effect on the displacements for a given pressure.

(31) There is an important difference in the structure of arc and furnace lines, which may affect their susceptibility to pressure displacement.

(32) The study of metallic spectra between λ 2500 and λ 7500 at various temperatures in the electric furnace has disclosed many new groups of lines, some of which are very susceptible to temperature change.

(33) A comparative study of arc and furnace lines shows that the variations of relative intensity in different parts of the arc correspond closely with those observed in the furnace at different temperatures.

(34) The relative richness of arc and furnace spectra is very different for different elements.

(35) A study of photographic processes emphasizes the great obscurity of the subject and the dependence of the plate manufacturers upon empirical methods. Certain promising lines of research are pointed out in this report.

STAFF.

The Director returned to his regular duties in October 1911, after an absence of 16 months on account of illness. His special researches of the present year include the study of the magnetic field and the theory of sun-spots, the spectrum of the chromosphere, and attempts to detect the general magnetic fields of the sun and certain nebulæ. During the Director's absence Mr. Adams served as Acting Director, carrying on all departments of the Observatory in the most efficient and satisfactory manner. He has also continued without interruption his work in charge of the Department

of Stellar Spectroscopy. Prof. F. H. Seares has remained in charge of the Computing Division and the editorial work, and has carried forward his researches in stellar photometry with the 60-inch reflector. He has also made a trip to Europe, to investigate the possibilities of improving photographic processes. Dr. Arthur S. King has continued his investigations as superintendent of the physical laboratory. Dr. C. E. St. John has been engaged in spectroscopic work on the sun with the 60-foot and 150-foot tower telescopes. Mr. Ferdinand Ellerman, Dr. Arnold Kohlschütter, and Mr. Charles Backus have continued the daily observations with the 5-foot spectroheliograph. Mr. Ellerman and Dr. Kohlschütter have also assisted the Director in work with the 150-foot tower telescope. Mr. H. D. Babcock has carried on a variety of laboratory investigations, and has been associated with the Director in attempts to detect the general magnetic field of the sun and nebulæ. Mr. F. G. Pease has continued his systematic photographic study of nebulæ and star-clusters with the 60-inch reflector, in addition to his work of designing instruments. Dr. E. A. Fath has been engaged in several investigations with the 60-inch reflector, and has photographed the spectrum of the Milky Way with a low-dispersion spectrograph kindly loaned by Director Campbell, of the Lick Observatory. On account of his appointment as professor of astronomy at Beloit College, he resigned from the Observatory staff on September 1. Dr. Arnold Kohlschütter, who was appointed assistant January 1, has devoted most of his time to stellar spectroscopic observations and the classification of stellar spectra.

Prof. J. C. Kapteyn, Research Associate of the Carnegie Institution of Washington, spent the months of July, August, and September on Mount Wilson in continuation of his studies of star-streams and related problems. Prof. E. E. Barnard, of the Yerkes Observatory, made visual and photographic observations of Mars and Saturn with the 60-inch reflector during November and a part of December. Prof. Carl Störmer, of the University of Christiania, Research Associate of the Carnegie Institution of Washington, who visited the Observatory during June and July, has made a mathematical investigation of the distribution of ions in the solar atmosphere as affected by the magnetic field in sun-spots. Prof. Ejnar Hertzsprung, of the Potsdam Observatory, is staying on Mount Wilson from July to October for the purpose of measuring the effective wave-length of faint stars with the aid of a large grating, used in conjunction with the 60-inch reflector. Dr. J. A. Anderson, on leave of absence from the Johns Hopkins University, arrived in Pasadena on September 10. He will superintend the construction of a ruling machine for diffraction gratings, designed by himself and Mr. Pease. Mr. P. J. Van Rhyn, of Groningen, Holland, joined the Observatory as a volunteer assistant in July, and Dr. Adrian Van Maanen, a graduate of the University of Utrecht, spent some weeks on the mountain in the same capacity during July and August. On September 1 Dr. Van Maanen was appointed a member of the Observatory staff.

Mr. C. G. Abbot, Director of the Smithsonian Astrophysical Observatory, visited Mount Wilson in the spring before going to Algiers, where he continued the daily observations of the solar constant of radiation begun there last year. Mr. F. E. Fowle has carried on the regular solar-constant work at Mount Wilson during Mr. Abbot's absence.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Direct Photography of the Sun.

As in previous years, direct photographs of the sun have been taken on all clear days with the Snow telescope. The absence of spots during a large part of the year makes this series of less interest than usual, but the plates serve to record faculæ, and also the structure of the photosphere, when the seeing is good enough for this purpose.

Work with the 5-foot Spectroheliograph.

The routine work with the 5-foot spectroheliograph has been continued on every clear day, but the low state of the solar activity has greatly reduced the number of calcium (H_2) flocculi showing interesting structure. The plates have served mainly for the measurement of the areas of the flocculi and prominences, in continuation of the work of former years.

The use of the 5-foot spectroheliograph for the photography of the hydrogen flocculi has been criticized by M. Deslandres on the ground that the camera slit includes the whole of the $H\alpha$ line, so that the images representing the higher and lower levels are superposed. In view of the fact that the vortex structure of the $H\alpha$ flocculi is beautifully shown by this instrument (with which it was first detected), the validity of the criticism may be questioned. The existing evidence indicates that these flocculi probably follow the lines of force of the magnetic field produced by the spot vortex. If so, they do not lie in a single plane, but on a surface of revolution more or less conical in form. Hence they should be best shown by an instrument which combines in a single image the flocculi of different levels. For certain studies of these flocculi, high-dispersion instruments, permitting the isolation of any desired part of the $H\alpha$ line, are of course required. But in such important investigations as those of Professor Störmer,* photographs showing the flocculi of different levels projected upon a plane are essential.

A second criticism by M. Deslandres is better founded. He points out that the camera-lens and the prisms of this instrument are unnecessarily large, in view of the fact that the collimator-lens forms a reduced image of the concave mirror of the Snow telescope at a distance of 65 inches (1.6 m.) from its optical center. This important fact was overlooked in designing the spectroheliograph. As the reduction in the diameter of the beam is sufficient to permit it, the second prism has been cut down to a height of 4.5

* See page 182.

inches (11.4 cm.), thus yielding a valuable additional prism for use in the focal plane stellar spectrograph.

A rheostat has been provided to vary the speed of the spectroheliograph motor, thus giving a more perfect control of the exposure-time than the system of change-gears formerly permitted.

The 150-foot Tower Telescope.

The year has marked the completion of this instrument, after long delays occasioned by the difficulty in obtaining a suitable object-glass of 150 feet focal length. As mentioned in the last report, the 12-inch triple objective at first supplied by the makers was defective and had to be replaced by a visual objective of the ordinary two-lens type. This gave poor definition, and new glass disks were obtained for a third attempt, which proved to be very successful. The third objective was delivered by Brashear in May, and was immediately mounted in the telescope, where it has been in regular use for a variety of investigations.

The 75-foot combined spectrograph and spectroheliograph was completed in December, and the 12-inch objective, of 60 feet focal length, which belongs to the old tower telescope, was then transferred to the new tower, in order that observational work might begin before the completion of the 150-foot focus objective. The preliminary tests were most satisfactory in all respects save one—the focal length varied at different hours of the day, and the solar image gave evidences of astigmatism near noon. Experience with the 60-foot tower having shown that the rise in temperature of the mirrors from night to day would probably produce such effects, water-jackets surrounding their edges were provided, but during the winter these were not needed. In July the higher temperature and the use of the 150-foot focus objective rendered the changes far more conspicuous. The slight astigmatism previously found gradually grew more marked, and finally it became evident that the image was not merely astigmatic, but multiple. This was accompanied by increased focal change, amounting in some cases to 5 feet (1.5 m.) in a few hours. In the hope of preventing such changes, a steady circulation of water, kept at a nearly constant temperature, was maintained in the water-jackets covering the edges and backs of the mirrors. As soon as equilibrium was established the astigmatism completely disappeared and the change of focal length was reduced to a small fraction of its former amount. Long exposures with the spectroheliograph may now be given without interference from this cause.

On account of the great height of the new tower (176 feet to top of dome) doubts have been expressed by various writers as to its stability. The work of the last year proves these fears to be groundless. So delicate an operation as the photography of the "flash" spectrum has been carried out when the wind was blowing 20 miles an hour, and there has never yet been an occasion when it was necessary to stop work because of trembling of the image. In another respect the tower has also met our hopes. The defini-

tion of the solar image is much better than that of the Snow telescope after the early morning hours. There is no convection up the vertical tube, and the protection of the beam from the warm air rising from the heated earth is doubtless the cause of the improvement.

The 75-foot spectrograph has also proved to be very satisfactory. With the Michelson grating the definition of the solar spectrum is excellent in the first three orders; in the third spectrum, where the distance between the D lines is over an inch, both D_1 and D_2 are clearly double. A large number of excellent photographs of spectra have been taken with the focal length of 75 feet (22.88 m.), and for some work the spectrograph has also been used with a focal length of 30 feet (9.15 m.), since the exposure times are of course much shorter in this case. The ease with which the base of the instrument can be shifted from the bottom of the well to the 30-foot level is a valuable feature of the design.

Another advantage of this instrument is the possibility of changing the dispersion through a very wide range without disturbing the adjustments. For example, the following series of photographs of a sun-spot group might be taken in rapid succession:

(1) Structure of the group, using the instrument as a spectroheliograph, with the camera-slit set on the continuous spectrum.

(2) Calcium (H_2 or K_2) flocculi, integrating the phenomena of different levels.

(3) Hydrogen ($H\alpha$) flocculi, showing the vortex structure.

A table at the base of the instrument is then rotated, bringing a 60° prism or a grating into position.

(4) High-level hydrogen flocculi, using center of $H\alpha$.

(5) High-level (H_3 or K_3) calcium flocculi.

If $H\alpha$ indicates radial motion, a double mirror is rotated into position beneath the prism, replacing the single mirror used before. This gives two images of the spectrum from the same slit.

(6) Ascending and descending hydrogen flocculi (two camera-slits, one set on violet edge of $H\alpha$, the other on red edge).

Additional spectroheliograph images, with higher dispersion or with other lines, may be taken if desired. The instrument is then used (with a grating) as a spectrograph, for the following additional record:

(7) Magnetic survey of the spot group, showing polarity and strength of the field in different regions and at different levels. Single exposure with multiple slit and polarizing apparatus.

(8) Radial motion of spot-vapors, using multiple slit without polarizing apparatus.

(9) Spectrum of the umbra with high dispersion, for identification of spot-lines, determinations of pressure, strength of magnetic field at different levels, etc.

In such a program, the order in which the photographs are taken and the size of the solar image employed will naturally depend upon the special re-

quirements of each class of work. The ease with which the diameter of the image can be changed, by swinging into place objectives of 30, 60, and 150 feet focal length, and the equal facility of changing the dispersion by a device similar to the multiple nose-piece of a microscope, renders possible a great variety of work in a limited time.

The combined spectrograph and spectroheliograph is also designed for the photography of the spectrum of the chromosphere ("flash spectrum"), the comparative study of the spectra of center and limb, the measurement of the solar rotation, the determination of the pressure at different levels in the solar atmosphere, and for various other purposes.

The auxiliary apparatus includes a reflecting slit, especially adapted for the photography of the spectra of pores and other minute regions; a device for securing uniform density of the spectra of umbra, penumbra, and photosphere in a single exposure; a special guiding device, to maintain any part of the sun's image on the slit with great accuracy throughout an exposure; a parallel-motion apparatus, to facilitate accurate orientation of the instrument; polarizing apparatus, with simple and compound quarter and half wave plates for various wave-lengths; and an electric arc for comparison spectra.

General Magnetic Field of the Sun.

In the absence of sun-spots and other local disturbances, which might tend to obscure the general phenomenon, an attempt has been made to observe any slight Zeeman effect due to the weak magnetic field of the sun.

Assuming that a moving molecule carries a magnetic field with it, Schuster has calculated that the magnetic intensity of the sun should be about 440 times greater than that of the earth, if both are due to the effect of rotation.* With similar considerations in mind, the Director attempted in 1908 to detect the sun's field with the 60-foot tower telescope. The extremely small line displacements observed at that time could not be safely attributed to the general field, as it was necessary to rotate the Nicol prism between exposures, and the unavoidable change in the illumination of the grating might easily result in spurious shifts. A compound quarter-wave plate, consisting of a number of mica strips 2 mm. wide, the principal sections of successive strips making an angle of 45° with the axis of the nicol and 90° with each other, was accordingly ordered from Werlein. Thanks are due M. Cotton for valuable advice and assistance in the supervision and testing of this and other polarizing apparatus obtained from the same maker. An investigation was also undertaken of the polarization phenomena caused by the mirrors of the tower telescope, which might lead to erroneous results unless measured and corrected. The special polarimeter built for this purpose permits the polarization corresponding to any position of the sun to be measured in a few moments, either for the 60-foot tower or for the different arrangement of the mirrors in the 150-foot tower.

* Proc. Phys. Soc. London, vol. 24, part 3, p. 127, April 15, 1912.

The first tests with the compound quarter-wave plate were made by the Director with the 60-foot tower in October, but no appreciable shifts of the solar lines could be detected. They were continued in the third-order spectrum of the 75-foot spectrograph of the 150-foot tower in January. The slit was set on the sun's axis, with its center at 45° north or south latitude, the purpose being to detect any slight displacements of the lines due to the extinction of their elliptically polarized red and violet edges by the nicol and successive quarter-wave strips. Telluric lines on the same plates afford excellent checks, as their displacements rarely exceed 0.0002 Ångström. It may be doubted whether so high a degree of precision has been obtained in any previous measures of lines in the solar spectrum. Most of the lines of solar origin are much less sharp, and consequently the errors of measurement are decidedly greater, especially in the less refrangible region, where the largest magnetic effects are to be sought.

A selected list of lines in the region λ 5810 to λ 5930, having large separations in the laboratory, showed no displacements exceeding 0.0006 Ångström. Two iron lines, and a line of unknown origin, nevertheless gave displacements as great as 0.0024 Ångström. Photographs were accordingly taken north and south of the equator, and at different latitudes. The plates, as measured by Miss Lasby, gave opposite signs for the displacements in the two hemispheres, and values decreasing from a maximum near 45° to about zero near the equator. As a check on the method, a half-wave plate, inserted between the quarter-wave and nicol, was rotated to different positions, so as to reverse the direction of the shift for a given quarter-wave strip, or eliminate it altogether. In other cases the compound quarter-wave plate, used without the half-wave plate, was inverted, to determine whether the sign of the displacements depended upon its position. Almost without exception both the sign and the order of magnitude of the shifts agreed with the theory, all of the measurements being made by an observer who knew nothing of the conditions under which the plates were taken.

The same plates were then measured by other observers, who failed to confirm the above results. An extensive series of photographs was then undertaken in the second order of the Michelson grating, as the lines in question were more diffuse in the third order. A form of parallel-plate micrometer, suggested by Mr. Pease, was employed for measuring the plates. The means of a great number of measures, however, failed to confirm the results previously obtained by a single observer on the third-order plates. At present it is impossible to account for these results, if they do not actually represent the general field of the sun.

The investigation is being continued, but on account of the exceedingly small quantities involved, and the fact that the lines showing apparent shifts are not quite as sharp as some others in the solar spectrum, the work of measurement is difficult.*

* Dr. Van Maanen has since confirmed Miss Lasby's results for the plates of the first series, and a new series of photographs will be made soon.

Spectrum of the Chromosphere.

The investigation of the spectrum of the chromosphere, for the purpose of determining with the greatest possible precision the wave-length, level, and origin of all the bright lines that can be photographed with the 150-foot tower telescope, is being continued by the Director and Mr. Ellerman, assisted in the measurements by Miss Burwell. Unfavorable weather conditions and the astigmatism of the mirrors (now overcome) have hindered the observations, and few satisfactory negatives have yet been obtained. The work will necessarily proceed slowly, as photographs showing the maximum number of bright lines can be made only when the atmosphere is exceptionally steady. In connection with this investigation, Mr. King will study in the laboratory the anomalous dispersion of a number of lines which occur in the chromosphere, in order that a further test may be made of the theory of Julius.

A Sun-spot Hypothesis.

The following tentative working hypothesis of sun-spots is proposed by the Director merely as a guide to further research. As the result of an eruption, or some other cause tending to produce rapid convection, a gaseous column moves upward from within the sun toward the surface of the photosphere. Vortex motion is initiated by the difference in velocity of adjoining surfaces or by irregularities of structure and is maintained by convection. The circulation in the vortex is vertically upward and then outward along the photosphere, as in a terrestrial tornado. Expansion produces cooling at the center of the vortex, and a comparatively dark cloud (the umbra) results. As in Harker's electric-furnace experiments,* a rapid flow of negative ions sets in towards the cooler gases at the center from the hotter gases without. These ions, whirled in the vortex, produce a magnetic field. The descending gases (especially hydrogen) in the higher atmosphere of the sun are drawn in toward the pole of the magnet along the lines of force, as in Birkeland and Störmer's theory of the aurora. This accounts for the configuration of the hydrogen ($H\alpha$) flocculi, as shown by the spectroheliograph.

Hitherto we have assumed the spot to be single. The typical spot-group is double, the line adjoining the two spots making only a small angle with the equator. The polarities of the two principal spots (smaller companions are usually present) are opposite, and the hydrogen ($H\alpha$) flocculi surrounding a bipolar group resemble the lines of force about a bar magnet. Two alternative hypotheses may be offered to account for these phenomena. According to the first, the lower extremity of the vortex of the primary spot, curved like many terrestrial tornadoes, turns up to meet the photosphere, thus producing a horse-shoe vortex. As in the case of single (unipolar) spots, the hydrogen and other high-level gases flow toward the two members of the group along the lines of force. According to the second view, there are

* See Nature, July 18, 1912.

two distinct vortices, with nearly radial axes. The necessary criteria of selection can probably be found by a comparative study of the principal members of a bipolar group, special attention being directed to the inclination of the axes of the vortices to the line of sight (if it can be determined by the Zeeman effect), the direction of flow (inward or outward) of the vapors at different levels, and the proper-motions, temperature, and pressure of the two spots.

Professor Störmer's Investigations.

Prof. Carl Störmer, of the University of Christiania, Research Associate of the Carnegie Institution of Washington, has been engaged for some years in a study of the aurora, on the theory that it is caused by ions entering our atmosphere from the sun under the influence of the earth's magnetic field. As it seemed possible that the application of similar methods to an investigation of the hydrogen ($H\alpha$) flocculi would lead to important results, Professor Störmer was invited to spend several weeks at the Observatory in June and July.

A preliminary study of the spectroheliograph plates led him to the conclusion that, in the case of single spots, the simplest elementary curves resembling the hydrogen flocculi in form are logarithmic spirals. An additional reason for adopting these curves as a first approximation was the fact that the current lines in terrestrial cyclones are also approximately logarithmic spirals.

It then became necessary to solve the following mathematical problems for application to sun-spots:

(1) Find the magnetic field in space due to a plane current sheet, in which the current lines are all concentric logarithmic spirals of the same form.

(2) Find the field of two such current sheets, situated in parallel planes with common axis and connected by a short central helix (model of a cyclonic vortex).

All the necessary mathematical formulæ were derived and brought into a form suitable for convenient numerical computation.

The next step, the calculation of the magnetic field of two opposite whirls, corresponding to the bipolar type of sun-spots, follows at once from the application of the formulæ, and the computation of the numerical data in each case then becomes only a question of time. The case of a number of vortices of different signs can be treated in the same manner. The application of these results to bipolar and multipolar configurations of hydrogen flocculi will be made later.

The theory of the sun's general magnetic field, on the hypothesis that it is due to the rotation of an electrically charged sphere, was also investigated. The results will be compared with Professor Störmer's researches on the form of the coronal streamers, based on the hypothesis developed in the Comptes Rendus of February 20 and March 6, 1911.

STANDARDS OF WAVE-LENGTH.

As a practical test of the degree of precision obtainable by the plane-grating spectrograph, the absolute wave-lengths of a score or more of iron lines belonging to the same pressure groups as the international standards of the second order were determined with similar instruments of 30 feet focal length on Mount Wilson and in Pasadena by Mr. St. John, assisted by Miss Ware. The mean of the differences, Pasadena–Mount Wilson, taken without regard to sign, is 0.0010 Ångström; the mean probable error for the Pasadena series is ± 0.0007 Å., and for the Mount Wilson series, ± 0.0006 Å. These results are of interest in view of the possible use of the plane grating in absolute measurements and in a study of the comparative precision obtainable by plane and concave gratings in such measurements.

In the case of lines not belonging to the same group as the standards, when classified according to displacements under pressure, the measurements on the Mount Wilson and Pasadena plates showed consistent differences in wave-length that seemed only referable to the difference in atmospheric pressure between the two stations. The elevation of the Mount Wilson station is 5,886 feet (1,794 m.); the elevation of the Pasadena laboratory is about 800 feet (244 m.), so that the difference in altitude corresponds to slightly less than one-fifth of an atmosphere. When lines of the same widths on the two series of plates were compared it was found, (1) that in the case of 20 lines the wave-lengths determined from the Mount Wilson plates were on the average 0.009 Ångstrom shorter than those from the Pasadena plates; these lines belong to group *d* of Gale and Adams, which consists of lines showing enormous displacements to the red under pressure, and, therefore, displacements to the violet under the decreased pressure on Mount Wilson; (2) that in the case of 15 lines the wave-lengths from the Mount Wilson plates were on the average 0.014 Å. longer than those from the Pasadena plates. Upon the plates taken by Gale and Adams under a pressure of 9 atmospheres, the maxima of these lines are greatly displaced to the violet, the lines, however, being too diffuse for measurement. There is, therefore, sufficient reason for considering them a distinct group, the members of which are displaced to the violet under pressure, and hence to the red under the decreased pressure on Mount Wilson.

The investigation offered the means of examining the relative accuracy of the international standards of the second order, which had been questioned at the Mount Wilson meeting of the International Union for Coöperation in Solar Research. In the regions λ 5371 to λ 5658 and λ 5975 to λ 6494 there are 21 standards of the second order, and of these 16 were reported as requiring adjustments of 0.001 to 0.011 Å. Such results, if confirmed, would tend to destroy confidence in the precision of the interferometer method of obtaining standards of wave-length. With standards 50 Å. apart on the present photographs an error in one of them of 0.002 Å. is clearly shown.

The result of this examination of the 21 standards indicates that there are no errors exceeding 0.001 Å., except in the case of one line (λ 5434), where the error is 0.002 Å.

Thus far 100 lines have been studied in the region λ 5371 to 6494, and of this number 21 are international standards of the second order. Seventeen of these were found entirely suitable for such standards; 25 of the 100 lines are suitable for tertiary standards; 44 are unsuitable for standards because of excessive displacement under pressure accompanied with dissymmetry; and 14 are provisionally classified as of questionable utility.

The investigation has shown that, in the selection of a series of standards, attention should be given to pressure displacement, and only such lines included as do not differ greatly in this respect, if the standards are to be equally available for stations at low and high altitudes. This becomes increasingly important as the series is extended to the red, when the rapid increase of pressure displacement with wave-length is considered.

In his study of solar and metallic spectra, Rowland always found displacements between solar and metallic lines of 0.01 to 0.02 Å., which he attributed to instrumental errors. Similar capricious results were encountered in an investigation begun by Mr. St. John some time ago with the spectrograph used in connection with the 60-foot tower telescope on Mount Wilson, but with the new spectrograph of the 150-foot tower telescope a series of plates of the solar and iron arc spectra have been obtained that are free from the relative displacements arising from instrumental imperfections and adjustments. Three sources of error have been associated with the instability of the apparatus, the illumination of the grating, and the centering of the solar image. The first is overcome by the massive construction of the spectrograph, the head of which has a weight of approximately 4,500 pounds (2,000 kg.), and when clamped in position can not be appreciably disturbed by the necessary manipulations. The second is eliminated by the large diameter, 15 inches (38 cm.), of the cone of sunlight incident upon the grating which the great focal length, 75 feet (22.9 m.), of the spectrograph permits when the 12-inch objective of 60 feet focal length is used to form the solar image on the slit. The third source from which misleading displacements may arise is avoided by fixing the slit rigorously on the axis of the centering circles. The error introduced from noncentering of the solar image may be large; with the image now used (diameter 162 mm.) the solar lines are shifted 0.001 Å. by solar rotation when the slit is 2 mm. from the center of the image, and with small images the error may be much greater.

With the present equipment an investigation involving the comparison of the arc and the solar spectra of iron has been resumed. The same plates are being used for an examination of the relative accuracy of the international standards of the second order and the determination of the wave-lengths of the tertiary standards in connection with a series of plates of the arc spectrum of iron taken in the Pasadena laboratory.

Radial Motion in Sun-spots.

Additional plates have been taken during the year by Mr. St. John in the course of his investigation of the radial motion in sun-spots. These have all been measured, yielding results in harmony with those previously obtained, which indicate the following mean conditions:

The calcium vapor as represented by the H and K lines and the hydrogen as shown by the $H\alpha$ line flow inward across the outer boundary of the penumbra with velocities of 1.9 km. and 1.5 km. per second, respectively; the vapors of sodium and magnesium flow inward with velocities of 0.2 km. and 0.4 km. per second, respectively; the vapors of aluminum and iron, which are the sources of the strong *Al* line λ 3961, intensity 20, and of the *Fe* line λ 4271, intensity 15, have mean velocities of 0.0 km. and 0.1 km. per second inward respectively. The mean provisional results for iron, based upon a large number of lines of low and moderate intensities near λ 5200, are shown in the table.

Intensity	Outward velocity per sec.
	km.
6	0.49
5	0.58
4	0.64
3	0.69
2	0.75
1	0.85
0	0.90

Similar results appear in the case of other metallic vapors producing lines of low and moderate intensities, though the velocities deduced from lines of equal intensities for different elements are not equal. This offers a means of determining the relative distribution of the constituents of the solar atmosphere or the relative levels at which lines of given intensities have their origin, as referred to some standard, such as iron, represented by a large number of lines in the solar spectrum. For example, it appears that the lines of titanium are produced at a higher level than lines of the same intensity due to iron.

Three regions are indicated in the solar atmosphere surrounding spots, with the following characteristics at the different levels:

(1) The upper chromosphere, in which the movements are directed inward, as shown by the H and K lines of calcium and the $H\alpha$ line of hydrogen.

(2) An intermediate region, in which are produced the D lines of sodium, the *b* lines of magnesium, and the strongest lines of aluminum and iron, in which the movement is sometimes inward and sometimes outward, the inward direction in general prevailing.

(3) A lower region, in which the movement is always directed outward, the velocity increasing with the depth or nearness to the photosphere, on the assumption that in general the weaker lines are associated with the lower levels.

THE SIXTY-INCH REFLECTOR.

During the year a new extension frame for the end of the tube of the 60-inch reflector has been completed, which admits of photographic work directly in the axis of the large mirror and thus eliminates one reflecting surface. Three spectrographs for use with this frame are available:

(1) A spectrograph with camera and collimator lenses of 46 cm. focal length and a dense flint-glass prism of 63° angle, for determinations of the radial velocities of faint stars.

(2) A spectrograph with quartz camera and collimator lenses of 5 cm. aperture and a 60° quartz prism.

(3) A spectrograph with collimator lens of 46 cm. and a camera-lens of 18 cm. focal length used with a 30° crown-glass prism. This instrument has been employed by Mr. Fath in observations of the spectra of spiral nebulæ, star-clusters, and very faint stars.

A spectrograph containing a concave grating of 100 cm. radius, for use at the 80-foot focus with the Cassegrain combination of mirrors, has been partially completed. A Pérot-Fabry interferometer has also been adapted for use in this instrument.

An 8 by 10 plate-carrier, for direct photography in the 100-foot Cassegrain focus, was completed in August, and used for the photography of nebulæ and for preliminary experiments in the determination of stellar parallaxes.

The large transmission grating, used with the 60-inch reflector by Professor Hertzsprung for his determinations of the effective wave-lengths of stars, has been presented to the Mount Wilson Observatory by the Astrophysical Observatory of Potsdam. Our appreciative thanks are extended to Director Schwarzschild for this valuable addition to the resources of the Observatory.

Other changes and improvements include the installation of a new switchboard, with an improved system of control for all quick and slow motions of dome and telescope; the addition of an extension to the observing platform; repairs of the driving-clock, clock-wind motor, and right-ascension quick motion, provision of a motor hoist for the canopy, an automatic safety stop on the dome shutter, observing ladder with elevating seat, etc.

Direct Photography.

The following photographs of nebulæ and star clusters have been taken by Mr. Pease in the principal focus of the 60-inch telescope:

Spirals: *N.G.C.* 1068, 2683, 2841, 4736, 5005 and 5545, 6412, 6478, 7177.
Spindles: *N.G.C.* 3115, 5866.
Globular Clusters: *N.G.C.* 4147, 5272, 5904, 6205, 6218, 6254.
Planetary Nebulæ: *N.G.C.* 6804, 6818, 6826.
Gaseous: *N.G.C.* 650, 1555 (Hind's variable nebula).

Several photographs were also made of *Nova Geminorum*, in the hope of detecting nebulosity.

The following planetary nebulæ were photographed by Mr. Pease with the Cassegrain combination giving an equivalent focal length of 100 feet:

N.G.C. 6210, 6543, 6572, 6818, 7009, 7662.

Some parallax plates and a few photographs of Mars and Saturn were also taken with the same arrangement. The work of Professor Barnard on these planets is described below.

Forty-eight plates, completing the program of the Kapteyn selected areas, were taken by Mr. Fath. An examination of these plates for nebulæ leads to the conclusion that, if the plates are fair samples, there are about 164,000 spiral nebulæ in the entire sky which could be photographed with an exposure of one hour with the 60-inch reflector, using Lumière Sigma plates.

A series of plates was taken by Mr. Fath through red and blue ray filters of certain regions of the Milky Way. The purpose of the investigation was to detect, if possible, any loss of light in space. The method adopted required the assumption that a large proportion of the stars should be of the same spectral type. This seemed to be the case from an investigation by Pickering, who found that the A-type stars condense toward the Milky Way and that the proportion of A type to all other types increases as the stars become fainter.

The plates taken seem to show definitely that the fainter stars are redder than the brighter ones. On the assumption that the type of spectrum was the same throughout, this would indicate a loss of blue light of the fainter stars due to their greater average distance. This explanation is not satisfactory, owing to other results noted below.

Photographs taken for the Harvard College Observatory include one with equivalent exposures on the regions surrounding *Nova Geminorum* No. 2 and the region containing the Harvard Polar Sequence, and several of clusters, to be studied by Professor Bailey.

Photographic Photometry.

Although the investigations in photographic photometry with the 60-inch reflector were interrupted by the absence of Mr. Seares during the months April to July, the following results may be reported: 231 plates have been obtained, chiefly for further investigation of the correction to the observed magnitudes depending upon the distances of the stars from the axis of the instrument, and for an independent determination of the magnitude scale of the Harvard Polar Sequence; 12 plates are of the Algol variable *RR Draconis*, which is of unusual interest because of its range of variation, extending from magnitude 9.70 to 13.50. With but few exceptions the photographs have been measured and fully reduced.

The distance error varies proportionally with the distance from the axis. For a given distance it also depends on the size of the photographic image. As previously reported, its effect is such as to increase the brightness of the brighter stars; for fainter stars its value is zero. Further investigation has shown that for the faintest images on the plate the effect is negative, that is, the observed is less than the real brightness.

The different values of the correction required for certain plates by stars of the same brightness and at the same distance from the axis referred to in

the report of the preceding year have been traced to small unsymmetrical temperature deformations of the mirror. The fluctuations in the average value of the correction from plate to plate seem also to be due to this cause. Coma, in the case of the reflecting telescope, is extremely sensitive to small changes of figure, and a small variation in temperature is sufficient to produce an appreciable change in the size of images not on the axis. Owing to the distribution of the light intensity within the image, an unsymmetrical deformation of the mirror must produce corresponding irregularities in the distance error when different directions from the axis are considered.

The changes of figure involved are usually so slight that, under ordinary conditions of seeing, it is quite impossible to study them in detail with the knife-edge when used visually. On this account arrangements were made whereby the actual state of the figure may readily be photographed, and the result above stated has been derived from a comparison of the photographic record of the figure with simultaneous determinations of the distance error.

In explanation of the observed irregularities in the distance error it should be stated that formerly it was not possible to cover the reflector with the canopy when the Cassegrain spectrograph was in position. As the arrangement of the program was such that the photometric observations immediately followed those with the spectrograph, part of the photometric plates were exposed when the mirror was in an abnormal condition. The instrument is now covered with the canopy at the end of each night's work, and as a result the difficulty has largely been eliminated.

From the experience thus far gained it appears that with care in the matter of temperature control reliable photometric results may be obtained through the use of an average value of the distance correction.

The results for the magnitude scale of the Polar Sequence are based upon 15 plates and include 31 separate determinations of the scale from magnitude 10.5 downward to 17.6, the lower limit being shown on but a single plate, however. Exposures with diaphragms of 32 and 14 inches and a wire-gauze screen, in combination with exposures with full aperture, were used for the derivation of the scale. The differences in scale for Mount Wilson and Harvard are as follows:

Range in magnitude.	No. of stars.	Mount Wilson-Harvard.
		mag.
10.5 to 11.5	6	−0.03
11.5 to 12.5	4	−0.02
12.5 to 13.5	6	+0.03
13.5 to 14.5	5	+0.03
14.5 to 15.5	5	−0.01
15.5 to 16.5	4	−0.13
16.5 to 17.5	7	−0.27

From magnitude 10.5 to 15.5 the deviations are insignificant. The divergence for the fainter stars requires further investigation. The mean results for the two diaphragms and the wire-gauze screen are in satisfactory agreement throughout. This was to have been anticipated, for, as previously reported, the diffraction effect in the case of the diaphragms is negligible over a range of 5 magnitudes. The extension of the scale in the direction of both brighter and fainter stars is now in progress.

Thirteen plates containing four exposures each were taken by Mr. Fath for the comparison of the magnitudes of the Kapteyn selected areas with those of the Pritchard-Kapteyn areas. These plates have not been measured.

STELLAR SPECTROSCOPY.

A large part of the stellar spectroscopic work done by Mr. Adams and Mr. Kohlschütter during the year has been a continuation of the determination of the radial velocities of certain selected stars, mainly of types A and B, whose motion is of particular importance in the study of star streaming. Between September 1, 1911, and September 1, 1912, about 850 spectrograms were obtained with the Cassegrain spectrograph, and all of the photographs have been measured and reduced by at least one computer. In most cases two or more measures are available.

Two modifications of the spectrograph have been made. The first was the substitution of a camera of 102 cm. focal length and one prism for the shorter camera of 46 cm. focal length and two prisms. This has been found of decided advantage in the study of the spectra of A and B type stars, which have few lines and do not require high revolving power. The exposure times with the two combinations are not far from equal, a slight advantage lying with the shorter camera. A second modification has been the use of the 46 cm. camera with a single prism for observations of very faint stars. This optical system was first employed in the case of *Nova Geminorum* No. 2 after the star had become too faint to be photographed with the more powerful apparatus, and it has proved of great value in the study of faint stars, especially of the solar type of spectrum. Under good conditions we have secured fully timed spectrograms of stars with a visual magnitude 7.2 in 40 minutes. The faintest star so far observed with this instrument is of magnitude 8.2 on the visual scale.

The principal results of the observations with the Cassegrain spectrograph during the year may be summarized as follows:

(1) The discovery of about 45 new spectroscopic binaries, making a total of about 95 so far found with this instrument. Many other stars are upon the list of probable binaries and are at present under observation. Most of these stars are of types A and B.

(2) The radial velocities of about 70 stars with spectra of types A and B which have constant radial velocities have been determined from three or more observations.

(3) One or more observations of about 140 other stars of types A and B have been secured during the year.

(4) The radial velocities of about 40 stars of types F to M, mainly fainter than magnitude 5.5, have been determined from three or more observations. Most of these stars are of known proper-motion and parallax, and accordingly their velocities in space can now be obtained. An interesting feature

of these results is the discovery of the largest apparently constant radial velocity so far observed. It is that of the star *Lalande* 15290, $7^h\ 48^m$, mag. 8.2, and amounts to −248 km. per second.

The discovery by Enebo on March 13, 1912, of a new star in *Gemini* afforded a favorable opportunity for a series of observations upon one of these important and remarkable objects. The star was observed as regularly as possible from March 22 until May 27, when it reached too great a western hour-angle for further observation. During this interval the brightness of the star decreased from 5.0 to 8.5.

The principal results of a study of the spectrograms are as follows:

(1) The changes in the character of the spectrum are similar to those found in the case of *Nova Persei* and other new stars, the decrease in brightness being accompanied by the disappearance of the dark lines, a weakening of the continuous spectrum, and a gradual approach of the spectrum to that found to be characteristic of planetary nebulæ.

(2) The radial velocity of the star is probably constant and about +10 km. per second.

(3) The displacements of the dark and the bright hydrogen bands, and their widths, appear to be closely proportional to wave-length, a result found by Campbell and Wright for *Nova Persei.*

(4) A marked similarity appears to exist between the spectrum of the *Nova* and that of certain *Wolf-Rayet* stars, both as regards the bands present and their relative widths.

(5) Our observations show no marked evidence of the presence of the spectrum of radium or of the radium emanation in the *Nova* spectrum.

(6) There appears to be considerable evidence for the presence of the nitrogen spark spectrum in the *Nova,* an identification suggested by Wright in the case of *Nova Lacertæ.*

(7) There is no evidence of circular polarization in the complex bright bands of the *Nova* spectrum.

Classification of Stellar Spectra.

During the year Mr. Kohlschütter has carried on the classification of the spectra of the stars photographed with the Cassegrain spectrograph. The system used was that of the Harvard Observatory, in which six types are distinguished, B, A, F, G, K, and M. By far the greater part of the spectra investigated belong to types A and B, although a considerable number of spectrograms of stars with known parallaxes, which belong to types F to M, have been examined as well.

The linear scale of the spectrograms is considerably greater than that usually employed for classification purposes. As a consequence a smaller extent of spectrum can be used than in the case of the lower dispersion photographs, and some lines, notably H and K, can not be employed as criteria for classification. On the other hand, the finer lines are much better

shown on the larger scale photographs, and the structure of individual lines is seen much more clearly. Accordingly, the classification is based for the most part upon a comparison of groups of lines as close to each other as possible, and nearly of the same intensity and structure. In the earlier B-type stars, for example, the so-called "Orion" lines are compared with the hydrogen and the helium lines, while in the later B stars the relative strength of the helium line λ 4472 and the magnesium line λ 4481 furnishes an extremely important and valuable criterion. The two lines are equal in stars of type B 8. In the A-type stars the line λ 4481 is compared with neighboring metallic lines as they begin to appear. A gradual increase in the number and intensity of these metallic lines is the distinguishing feature of the transition from A-type stars to F stars. With the F-type stars the hydrogen lines begin to decrease in width and intensity and can be compared with neighboring metallic lines. Care has been taken in such comparisons to avoid enhanced lines and other lines of a peculiar character.

The number of stars so far classified is 453, and the results are based upon about 1,500 spectrograms. Seventy of this number are stars with known parallaxes and mainly of types F to M. The remainder are for the most part of types B and A and are distributed in the following subdivisions:

B 0	12	B 5	10	A 0	42	A 5	10
B 1	2	B 6	8	A 1	21	A 6	5
B 2	6	B 7	10	A 2	46	A 7	1
B 3	29	B 8	59	A 3	20	A 8	5
B 4	7	B 9	46	A 4	4		

The high dispersion of the spectrograms made it possible to detect numerous peculiarities or differences in the spectra of stars of the same type. Especially important is the distinction between stars having sharp and those having hazy lines. A large proportion of the latter have proved to be spectroscopic binaries and this fact may be accountable for the character of the spectrum. Some prominent groups of peculiar spectra are as follows:

(1) Thirty-two stars which show very strong enhanced lines, sharp, for the most part. A provisional examination of the stars with known parallaxes seems to indicate that the stars with strong enhanced lines have a greater absolute luminosity than those not showing the enhanced lines strongly.

(2) Fourteen stars with very sharp lines. These belong to group *c* of Miss Maury's classification.

(3) Fifteen stars which show bright hydrogen lines.

(4) Eleven stars which show composite spectra. All of these stars are spectroscopic binaries, and in all cases the brighter component shows the earlier type spectrum.

The results of the classification agree closely with the Harvard results. There appears to be a slight systematic difference in the case of the earlier B-type stars, the stars with sharp lines frequently being put one or two sub-

divisions later than in the Harvard catalogue. The stars with hazy lines are in good agreement throughout.

Miscellaneous Stellar Spectra.

The spectra of 25 faint stars down to mag. 11.3 were obtained by Mr. Fath. A number of these were long-period *Algol* and *β Lyræ* type variables. It was thought that possibly these long-period variables might be of a different type from those of short period, but those investigated all show an early type spectrum, either B or A. With the small dispersion used these types can not be differentiated. Fifteen plates containing the spectra of 36 stars were taken by Mr. Fath with the quartz spectrograph. The stars were selected in such a way that on any one plate they should be of the same spectral type and magnitude but have very different proper-motions. It was expected that on the average the stars of small proper-motion, being farther away than those of large proper-motion, would show less density in the ultra-violet portion of the spectrum. The evidence from the plates, however, is not conclusive.

Spectra of Nebulæ and Globular Clusters.

The spectrum of the spiral nebula *N. G. C.* 4826 was photographed by Mr. Fath, with an exposure of $16^h\ 15^m$. The plate, though somewhat under-exposed, shows that the type of spectrum is analogous to that of the sun. The spectrum of the great star-cluster in *Hercules, N. G. C.* 6205, was also photographed with a total exposure of $15^h\ 35^m$. The negative is of good density and indicates that the cluster is composed largely of F and G type stars, the F type probably being more numerous.

Magnetic Field of Nebulæ.

Rotating charged bodies, such as we may suppose planetary and spiral nebulæ to be, should presumably give rise to a magnetic field the poles of which correspond approximately with the poles of rotation. Although it is very doubtful whether these fields can be detected with existing instruments, the Director and Mr. Babcock thought it worth while to make the attempt, as the 60-inch reflector is well adapted for the purpose. The object chosen in the first instance was the bright planetary nebula *N. G. C.* 6543. An exposure of 3½ hours with a Fabry and Pérot interferometer, mounted with collimator, camera, and right and left handed circular analyzers in the new steel frame of the concave grating stellar spectrograph, failed to show any trace of interference fringes. We therefore decided to use a 33-plate echelon, mounted with auxiliary spectroscope on the inclined pier south of the 60-inch reflector, its axis coinciding with the polar axis of the telescope and its slit in the focal plane of the coudé combination of 150 feet focal length. The analyzing apparatus, suggested by Mr. Babcock, consisted of a half-wave plate covering half of the slit, and a quarter-wave plate,

followed by a double-image prism supported just in front of the photographic plate. In the laboratory this arrangement gave excellent results with extremely weak fields. The brightest planetary nebula available when the apparatus was ready in August was Σ 6, and this was west of the meridian. The chief nebular line, though faintly visible, gave no trace on the plate with an exposure of 3 hours. The experiment will be resumed, with much longer exposures, when suitable objects become available.

INTEGRATED SPECTRUM OF THE MILKY WAY.

As noted in the last report, an exposure of about 65 hours was made by Mr. Fath with a small spectrograph on the bright portion of the Milky Way in *Sagittarius*. The negative indicated a solar-type spectrum. It was feared that this result might be due in part to a number of K-type stars in the vicinity, but as a photometric investigation has shown this fear to be groundless, it seems probable that the greater portion of the light from this part of the Milky Way comes from solar-type stars.

Another exposure of about 68 hours was made on another bright portion of the Milky Way in *Scutum Sobieski*. This plate shows exactly the same type of spectrum as the preceding. A third exposure of 74 hours of a region in *Cygnus* is essentially like the other two.

The two negatives, indicating that the greater part of the light from those regions of the Milky Way comes from G-type stars which are fainter than those studied by Pickering, may explain the result noted in the preceding section that the fainter stars of the Milky Way are redder than the brighter ones.

Photometric observations to determine the brightness of the sky, carried on through most of the year by Mr. Fath, are being continued by Mr. Van Rhyn.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

The study of the motions of the helium and the A_0 to A_3 stars has been continued. The following are the main features of the investigation during the year:

(1) Owing to the numerous determinations of radial velocity which have become available this year, mainly through the labors of the Mount Wilson and the Lick Observatories, a new and for the first time fairly reliable determination of the velocities of the helium stars, Stream I, and the A stars, Streams I and II, was carried through. The determination of this last velocity depends almost entirely on the Mount Wilson observations, which were made expressly for the purpose. The positions of the vertices were also greatly improved.

(2) As was stated in last year's report, the second stream should not be completely absent from the helium stars. This year a few more stars were found apparently belonging to the stream. The principal gain, however, is due to Mr. Kohlschütter's classification. As a result of his investiga-

tion the stars A (A_0) of Harvard Annals, vol. 50, were to a large extent subdivided, one part being found to approach more nearly the helium stars, the other part deviating somewhat more toward the later types. The number of B stars thus gained for the second stream has more than doubled the total number. Still, it will be necessary to strengthen considerably the data for radial velocity of these stars before even an approximate determination of the elements of the stream will be possible. It is planned to obtain such data during the coming year, not only for the helium stars, but also for the classes A_0 and A_1.

(3) The extent and the elements of the *Scorpius-Centaurus* and *Perseus* groups, which must be considered as subgroups of Stream I, were carefully investigated. Much attention was paid to the question whether the relatively small difference in the stream-motion of these two groups could possibly be due to systematic errors in Boss's Catalogue and in the determination of the radial velocities. The conclusion was reached that such an explanation was untenable and that, consequently, differences in the stream-motion in different parts of the sky must be admitted. With the exception of a relatively small group of stars in *Vela,* which may form a more intimately connected subgroup, nearly all the stars between galactic latitude $+30°$ and $-30°$ and right-ascensions $5^h\ 20^m$ and $16^h\ 30^m$ appear to belong to one of the two groups mentioned.

(4) In each of these groups the parallelism of the motion is such that parallaxes can be and were derived for those objects which have a sensible proper-motion ($\geqq 0''.017$). Near the vertices the accuracy of these parallaxes is of course rather small, but for the great majority of the stars they must be fairly reliable. For these stars we thus know both the position in space and the amount and direction of the linear motion. We can also derive the frequency-curve of their absolute luminosities. Such a determination is now being made.

(5) A beginning has been made in the study of the question as to what distance from our system the star-streams extend.

(6) It has already been noticed by several astronomers that there is a certain clustering of the helium stars in different parts of the sky. The same thing is also brought out by the study of the motions of these stars and to a certain extent of the A stars. It is the clustering in such groups as the *Pleiades,* the restricted *Perseus* group, the larger *Perseus* group, the *Scorpius-Centaurus* group, and the *Vela* group (all probably partial groups of Stream II). These local groups make the investigation of the stream-motion considerably more difficult. It becomes necessary to investigate them, at least to such an extent that they may be approximately separated from each other and from the rest. Such a study led to the discovery already mentioned, that a number of stars in *Vela* probably form a local group; and further to the belief that the *Ursa Major* group, already extended by Hertzsprung to widely separated regions of the sky, may even

comprise a considerably larger number of members than were found by that investigation.

(7) The curious fact was brought to light that all the somewhat extensive local groups of stars, for which the required data are known, move in space very nearly parallel to the Milky Way.

(8) Little was done on the study of the absorption of light in space. A few words may be said on the subject, however, in order to remove an apparently very general misapprehension. It can not be maintained that the existence of an appreciable absorption of light in interstellar space has been indubitably proved by the work done up to the present time. On the other hand, however, the investigations published and unpublished prove beyond a doubt that, in general, stars of the same spectral class and of equal apparent magnitude are redder the greater their distance from our system. This fact may be due either to absorption in space or to the influence of the absolute luminosity. For the purpose of deciding which of the two factors is the one really responsible for the observed phenomenon, the fittest instrument would seem to be a fairly powerful short-focus refractor with a large field, provided with an objective prism. As this Observatory will probably possess such an instrument in the near future, it seems better to delay the necessary observations until it becomes available. Meanwhile the fact that, other things being equal, the more distant stars are redder, must not be overlooked, as it is of extreme importance to astronomy, independently of the question as to which of the two factors is its cause; for it will be a criterion, and possibly even an approximate measure of parallax at distances where all other measures fail.

The work of Mr. Fath during the past year on the spectra of stars of the same magnitude and type of spectrum but of widely different proper-motions has, on the whole, helped toward the establishment of this fact. It is also worthy of note that certain stars classified by Mr. Kohlschütter, and found to be peculiarly faint in the violet portion of the spectrum, all have extremely small proper-motions.

Some time has again been devoted this year to work on the observing program of the 60-inch reflector. Last year a large number of B-type stars, especially such as were suspected of belonging to what is now generally called the second star-stream, were put on the program. In addition a number of A-type stars in both streams were included, the selection being made in such a way as to insure a good determination of the stream velocities. Finally, a few A-type stars suspected of belonging to the *Perseus* and *Scorpius-Centaurus* groups were added, together with the stars already referred to of large and small proper-motions, whose radial velocities, taken in conjunction with the other data, might furnish some evidence as to the redness of the distant stars.

In arranging the program for the coming year, obviously the best plan was to give especial attention to such stars as the preliminary investigation

had shown to be of most importance in their relation to the several streams. Accordingly, the following groups of stars were placed on the observing list:

(1) Distant A-type stars, which appear to belong to the second stream.

(2) Certain stars having spectra designated *c* according to Miss Maury's notation. These stars have been found by Hertzsprung to be very remote. A recent determination by Kapteyn and Hertzsprung from 45 stars with magnitude of 4.5 gave an average parallax of 0″.002. This is about the average parallax of A-type stars of magnitude 10.7.

(3) A-type stars, presumably members of the first and second streams, which are approximately 90° distant from the corresponding vertices of the streams.

(4) A-type stars of the second stream which have fairly large coefficients for the determination of the stream velocity.

(5) All the B, A_0, and A_1 stars which appear to belong to the second stream.

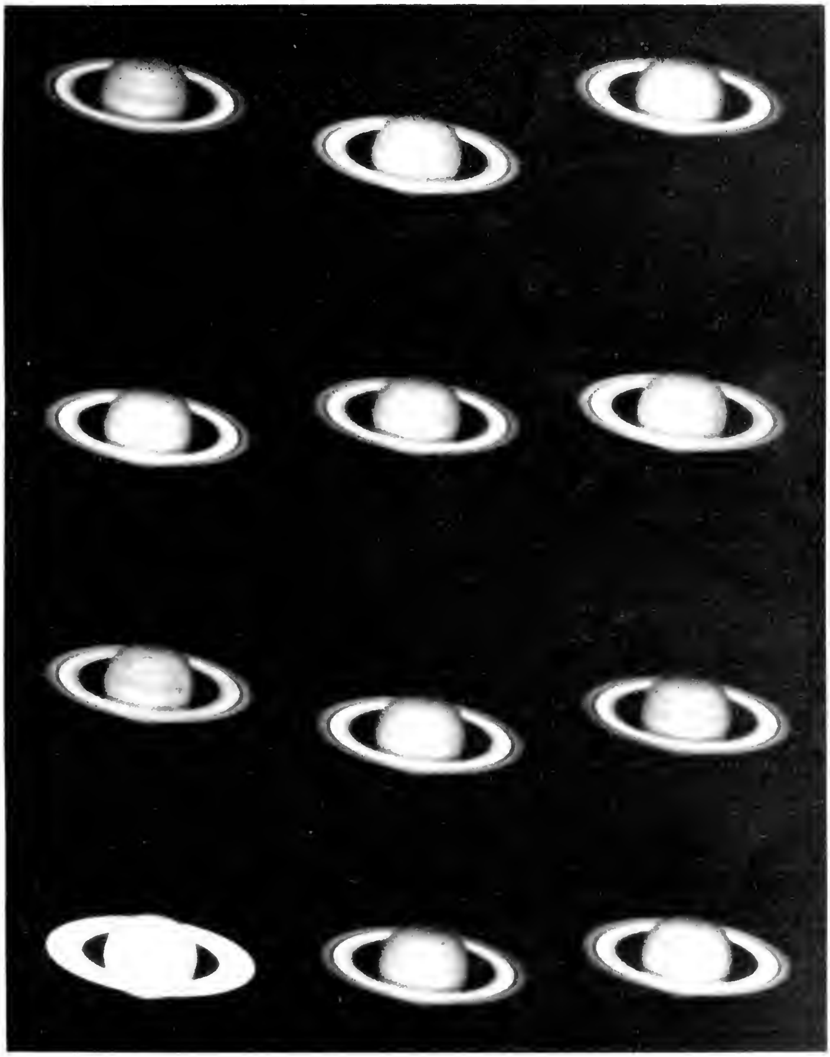
(6) Stars which belong to the *Ursa Major* group.

PROFESSOR BARNARD'S OBSERVATIONS.

Prof. E. E. Barnard, of the Yerkes Observatory, spent the month of November on Mount Wilson making photographic and visual observations of the planets Mars and Saturn with the 60-inch reflector. The season was not the best for such work, as bad conditions had set in with the winter rains. The selection of this season, however, was conditioned by the opposition of Mars, which occurred November 24, and was not therefore a matter of choice. The size of the image of Mars, which is a most important factor in photographing the planet, was much smaller than in 1909. The maximum values were: 1909, diameter 26″.0; 1911, diameter 19″.8.

On account of the regular program of observations with the 60-inch reflector, the observations were necessarily limited to certain nights, when the telescope was arranged for the work in hand. Most of the observations were made with the Cassegrain arrangement, giving an equivalent focal length of 100 feet, because of the increased scale value of the photographs. On a few occasions visual observations were also made in the principal focus of the telescope. The time required for the change from one arrangement of the telescope to the other prohibited the use of both arrangements during a single night. Some opportunities were therefore lost when visual observations might have been made to advantage with the shorter focal length.

A number of exposures on Mars and Saturn were obtained with the equivalent focal length of 100 feet, with the addition of an enlarging lens which had previously been employed in photographing Mars with the 40-inch Yerkes telescope in 1909. To secure increased sharpness of the enlarged image, the photographs of Saturn were made through a yellow color-screen



Photographs of Saturn, 1911, November 19. 60 inch Reflector, (100 foot Focus) at the Solar Observatory of the Carnegie Institution. Mount Wilson, California. Direct Enlargement Exposures. 10s. to 40s.

E. E. Barnard

on Cramer isochromatic plates. The results were satisfactory when the steadiness of the air was such as to permit of this enlargement. A photograph of Saturn, made in this way on November 19, is reproduced as Plate 4. The original negative shows the belt, polar caps, and rings very well defined. The Cassini division is strongly shown and feeble traces of the Encke division appear. The exposures were ordinarily from 10 to 12 seconds. One exposure of 40 seconds shows the crape ring fairly well, though the rest of the planet is of course overexposed in this case.

The photographs of Mars, which were made through a red screen on Seed Process plates, stained with a red sensitizing dye, are not so successful as those of Saturn, but are perhaps as good as could be expected under the circumstances. Though some of them show much detail, they are not as sharp as photographs taken in 1909 with the same instrument. On some of the negatives, however, a great deal of broken detail is shown in the region of Mare Cimmerium. The Solis Lacus region was photographed less satisfactorily. The telescope was not available for this work on any good night when the Syrtis Major region was visible.

In addition to the photographic work, some visual observations were made which were of the highest interest. Professor Barnard states that for some reason which he can not clearly explain, though it was perhaps due to an early observation with a reflecting telescope under unfavorable conditions, he had formed the idea that the reflector would not be satisfactory for visual work. This idea had been more or less corrected by a brief view of Saturn at the time of the meeting of the Solar Union in August 1910, which had impressed him very favorably, with the 60-inch telescope. The observations of Mars, however, fully convinced him of the suitability of the 60-inch reflector for visual work, and in many respects they proved to be superior to those made with large refracting telescopes. The principal reason for this was the remarkable purity of the image and freedom from color in the reflector, which is due to the entire absence of the secondary spectrum. Compared with the images of Saturn and Mars in the 60-inch, those in a refracting telescope have a muddy or dirty look. This was perhaps more striking in the case of Mars than in that of Saturn. Mars was almost colorless. There was a slight pinkish tinge to the image, giving one the impression of a globe whose entire surface had been tinted a slight pink color on which the dark details had been painted with a grayish colored paint, supplied with a very poor brush, producing a shredded or streaky and wispy effect in the darker regions. In the visual observations there was a better chance than in the case of the photographic work, for one could pick out moments of steadiness that would be lost to him during the exposures. The results in the case of Mars are said by Professor Barnard to be quite beyond his power of either describing or depicting. An artist could have studied the planet and given a representation of the structural details shown in the dark regions that would have conveyed some idea of

what was seen, but no one could accurately delineate the remarkable complexity of detail of the features which were visible in moments of greatest steadiness. Some sketches were made in an effort to show these features, but Professor Barnard considered his artistic skill entirely inadequate to the effort. In spite of the immense complexity of detail visible, he was unable to see any trace of the system of fine lines as drawn by Lowell.

The same freedom from secondary spectrum was especially striking in looking at the stars. The most impressive view Professor Barnard ever had of the Milky Way in a large telescope was with the 60-inch reflector in the principal focus. The stars looked like jewels on black velvet. The sky was rich and dark, and every star was a glowing, living point of light.

The region of *Nova Lacertæ* (Espin's star) was frequently examined with the focal length of 100 feet. Under good conditions there were a few stars visible which were fainter than Professor Barnard had seen in the 40-inch telescope while measuring the stars about the *Nova,* and the faintest stars he had measured were decidedly more noticeable in the 60-inch. Of course some of this increase of power was due to the greater transparency of the atmosphere at Mount Wilson.

Given an equal facility for handling the large reflector, Professor Barnard would prefer it for visual work on the planets to any of the large refracting telescopes with which he is familiar.

PROFESSOR HERTZSPRUNG'S INVESTIGATIONS.

Under a grant from the Prussian Government and the Prussian Academy of Sciences, Prof. Ejnar Hertzsprung, of the Astrophysical Observatory of Potsdam, spent four months (July–October) on Mount Wilson for the purpose of determining the effective wave-lengths of faint stars. The method employed consists in placing a large transmission grating over the end of the tube of the 60-inch reflector, and photographing the very short stellar spectra thus produced. The distance between the first-order images gives the effective wave-length, which serves as a measure of the color of the stars.

The large grating used in the investigation was made for the 60-inch reflector by Otto Toepfer, of Potsdam. It consists of 273 rubber bands 3 mm. in diameter, overspun with black cotton, and separated by spaces of the same width. The grating constant thus being 6 mm. and the focal length about 7,500 mm., the distance to be measured between the two spectra of the first order is about 1 mm. The grating gives excellent results, and a large number of photographs have already been taken.

The first-order spectra are about three magnitudes fainter than star-images observed without the grating. Photographs of the North Polar Sequence show good measurable spectra of stars down to the fifteenth photographic magnitude, in an exposure of one hour, on Lumière Sigma plates, with full aperture.

The principal objects hitherto photographed are:

(1) The North Polar Sequence to the fifteenth magnitude.

(2) The two regions right-ascension $13^h\ 50^m$, declination $+42°$, and right-ascension $21^h\ 15^m$, declination $+41°$, where stars down to the thirteenth magnitude, with well-determined proper-motions, are available.

(3) The cluster χ and *h Persei.*

(4) Faint stars having large parallaxes.

(5) Regions in the Milky Way showing great differences in star density.

Most of the plates have been taken with a 1-meter diaphragm, to increase the diameter of the measurable field. The size of the field can only be determined from actual measures of the effective wave-lengths, but it appears to be about 1° when the aperture is reduced to 1 meter.

For stars of magnitude 13.5 to 15.0 the mean error of the effective wave-length from a single pair of spectra is 29 Å. From the mean of two plates it is 20 Å., while the difference in effective wave-length between stars of types A and K (*Vega* and *Arcturus*) is about 200 Å.

Special attention will be paid to regions in the Milky Way where the star density changes suddenly, with a view to detecting any differences in color such as might be caused by the absorption of light in space.

PHYSICAL LABORATORY.

Investigations made in the physical laboratory in Pasadena during the year have been on electric-furnace spectra by Mr. King, and on special problems, dealing for the most part with magnetic phenomena connected with the solar work, conducted by Mr. Babcock.

The effect of pressure upon electric-furnace spectra, partially summarized in last year's report, was observed by Mr. King for groups of lines favorable for measurement at pressures ranging from 1 to 24 atmospheres, a collection of over 100 plates being obtained. The proportionality of displacement to pressure appeared to hold closely. The displacements given by the furnace, when compared with such measurements for the pressure arc as were available, gave consistently larger values for equal pressures. The difference for some groups of lines appeared greater than for others in the same spectrum, but as a rule the different character of the lines in furnace and arc made this relative difference uncertain as to its reality. Variations in the furnace conditions by the use of different temperatures, large and small quantities of radiating vapor, the presence of foreign vapors, compressed air instead of carbon dioxide, long and short columns of vapor, failed to show any distinct effect on the displacements. In the publication of the results it was pointed out that a fundamental difference exists in the structure of arc and furnace lines in general, with which their different susceptibility to pressure displacement may be connected, though the nature of this connection is obscure. The results of the investigation leave little room for doubt that a source of light such as the furnace gives displace-

ments considerably larger than are given by the arc at equal pressures, though, on account of the great difficulty in obtaining measurements of high accuracy in this class of work, more results from both arc and furnace are needed to establish the details of the difference.

The study of spectra given by the electric furnace at various temperatures has been continued, material being now on hand for a number of elements important in solar and stellar spectra. The range of spectrum photographed is from λ 2500 to λ 7500. The spectra to the red of λ 3900 are on large-scale plates and the results will be published in a series of papers, beginning with the spectrum of iron. The ultra-violet photographs thus far made are on a small scale and will be supplemented when a spectrograph of higher dispersion for this region is available. The leading features in this investigation are as follows:

(1) A number of lines are found for which low temperatures are especially favorable, some lines of this class being very faint in the electric arc.

(2) Other lines given by the furnace are classified according to the temperature at which they appear, the rate of growth in intensity being observed for increasing furnace temperatures and for the change from furnace to arc. Among such lines pairs are selected in various parts of the spectrum whose relative intensities in a given source of light where thermal radiation predominates are indicative of its temperature.

(3) Lines given by the radiation near the poles of the arc and usually appearing strongly in the spark (polar or enhanced lines) are absent or faint in the furnace spectrum, indicating that the electric discharge or some equivalent source of high energy (probably high temperature in celestial bodies) is required for the production of these lines.

(4) In harmony with earlier work, it is found that in the arc between iron terminals, the growth in intensity of spectrum lines observed in passing from the outer envelope to the core of the arc corresponds closely to the changes observed with increasing furnace temperatures, thus showing that the relative strength of some lines in the flame of the arc is due to reduced temperature rather than to chemical action. As the iron arc is easy of production and study, observers not having an electric furnace at disposal may employ the arc to obtain gradation in the intensity of iron lines which are qualitatively in agreement with those given by various temperatures of the furnace. The quantitative correspondence between a measured temperature and the resulting spectrum can be obtained only with the furnace.

(5) Striking differences appear between different elements as to the relative richness of the furnace and arc spectra. Thus the furnace spectra of titanium and vanadium show a larger proportion of arc lines than does that of iron, though the former elements have the higher melting-points.

(6) By the use of a small-scale spectrograph, the variations in radiation with wave-length throughout the spectrum has been observed for different temperatures.

Mr. Babcock has devoted most of the year to investigations in connection with the question of a general magnetic field on the sun and in nebulæ. The preliminary experimental work involved the design and use of instruments for measuring magnetic fields of the order of 100 gausses. The first measurements were made with a test-coil of known magnetic area in conjunction with a ballistic galvanometer, standard condenser, and standard cell. But a much better method was employed later, depending upon the deflection in the field of a coil of known magnetic area traversed by a known current and hung on a bifilar suspension. By this means an accuracy of about 0.5 per cent was obtained in measuring a field of 100 gausses. After adjusting the strength of the field by the use of this instrument to about 125 gausses, an electric spark was produced in it and photographs of the spectrum were taken, with the aid of special polarizing apparatus, to determine whether the Zeeman effect could be detected for such weak fields. Measurements of these plates yielded results in good agreement with the values calculated from the known displacements in a field of 17,500 gausses.

For this work it was found necessary to have an assortment of special preparations of mica for analyzing circularly and elliptically polarized light of different wave-lengths. Accordingly, about six weeks were devoted to the selection, mounting, baking, and testing of a stock of mica for this purpose, including a set of five compound quarter-wave plates of about 45 sections each, covering most of the visible spectrum, a similar set having only 5 or 6 sections each, a set of circular quarter and half wave plates, some in two sections and others in one, and several special preparations of half, quarter, and eighth wave mica. The preliminary testing, for the selection and classification of the mica, was made by a comparatively rough visual method. A photographic method was used for measuring the relative retardations for different wave-lengths of the finished specimens. The method depends upon the production of large relative retardations—from 30 to 90 wave-lengths—by plates of quartz cut parallel to the optical axis, which are inserted between crossed nicols. The addition of the mica to be tested causes the interference bands to shift different amounts for different wave-lengths, depending upon the retardation of the mica. In addition to the mounted preparations, a stock of unmounted mica was selected and classified.

After this a number of tests were made on two of our gratings for polarizing effects. For plane-polarized incident light vibrating in different azimuths, the state of polarization of the reflected diffracted light was determined for spectra of different orders.

During the absence of Mr. Seares in Europe Mr. Babcock spent much time on the study of the solar photographs for the detection of a general magnetic field, mainly in connection with the supervision and summarizing of the measures.

Mr. Babcock has also devoted three weeks to a further study of the frequency curves of magnetic triplets, a month to the photography of the Zee-

man effect in the red and yellow with the new magnet, and three weeks to photographic work on the spectrum of the iron arc for Mr. St. John. He has also carried on miscellaneous experimental work under the following heads: Mapping of magnetic fields of a series of spiral conductors lying in a plane, for Professor Störmer; photographing the spectrum of air with the quartz spectrograph; determination of the state of polarization of light, originally circularly polarized, after reflection from the two mirrors in the tower telescope; preliminary tests of a machine designed to produce a constant angular velocity.

The instrumental equipment of the laboratory has been increased by the purchase or construction of several pieces of apparatus, the most important being a large electro-magnet of the Weiss type, built by the Maschinenfabrik Oerlikon, of Zürich. The magnet is water-cooled, of 120,000 ampere-turns, and consumes 16 kw. when excited to full capacity. The maximum field obtainable has not been accurately determined, but the magnet furnishes from 30,000 to 40,000 gausses with the rather large pole separation required in the study of the Zeeman effect. The magnet has proved of great value, both for the ordinary high-field photographs of the Zeeman effect and for special experiments in weak fields. For this latter purpose it is superior to a smaller instrument on account of the large space available between its poles in which the field is very uniform, while the facility of its adjustment for pole-distance, angle between line of sight and field, etc., adds greatly to its usefulness.

A new direct-current generator set of 17 kw. was made up by the purchase of a 25-horsepower motor, which was connected with a dynamo already owned by the Observatory. This generator supplies power for the new electromagnet and has proved very useful by reason of its large capacity.

In addition, a small direct-current generator supplying 500 volts with currents up to 5.5 amperes has been installed for certain work with the electric arc requiring moderately high voltage.

A 4-inch Rowland concave grating of 1 meter radius has been mounted in a spectrograph of special design for the photography of the spectrum under low dispersion, including the ultra-violet region. As the instrument is adjusted, a first-order spectrum approximately normal from λ 2000 to λ 8000 is obtained. The long range of spectrum photographed at a single exposure is often a distinct advantage. As used with the electric furnace, simultaneous photographs are made with this instrument and with the Littrow spectrograph, thus obtaining for the same condition of the light-source a long range of wave-lengths, together with a high-dispersion plate for a selected region.

A concave grating of 15 feet radius has been obtained, for which a mounting is being designed. This spectrograph will in general follow Rowland's plan, but will be placed vertically in the laboratory well. The advantages of a concave grating of moderately high dispersion will thus be combined with the features which have given good results with the plane gratings.

Other additions to the optical equipment are a Pulfrich refractometer with accessories for use with monochromatic light, a 4-inch plane grating having bright spectra in the first and second orders, and a number of pieces of polarizing apparatus.

COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

Miss Eda Bowman was appointed to the division on February 1, but after a few weeks' service she was obliged to give up the work on account of ill health. Her time was devoted to the measurement and reduction of photometric plates.

During the year Miss Burwell has been engaged chiefly in work relating to solar and stellar spectroscopy. She has made measures on solar magnetic field plates and has determined the wave-lengths of the standard lines used in the radial-velocity determinations of stars from spectra of the sun's center. She has made a careful study of the intensities of the spectrum lines of *Arcturus* for the region λ 4250 to λ 6650, and has obtained the intensity curves for *Nova Geminorum* from 14 spectrum plates. She has further made measures with the tower polarimeter for a study of the polarization produced by the mirrors of the 150-foot tower telescope, and has examined 45 laboratory pressure plates for the determination of the character of the reversals of the enhanced lines. Miss Burwell is at present engaged in the measurement of chromosphere plates.

Miss Ensign has devoted the greater part of the year to the measurement and reduction of 920 stellar spectrograms, she has assisted in the preparation of tables used for the solution of the Hartmann formula, has calculated constants employed in reducing observed radial velocities to the sun, and has also given assistance in copying, recording, and proof-reading.

Miss Helen High, since her appointment to the division on June 1, has measured 60 pairs of solar magnetic field plates with the parallel-plate micrometer, and has assisted Mr. Fath with reductions and calculations relating to nebulæ.

Miss Lasby has continued to devote the greater part of her time to stellar spectra. She has measured and reduced 750 plates. Several weeks were spent in the preparation of tables for facilitating the reduction of stellar spectra, and a month was devoted to miscellaneous measures on solar magnetic field plates, laboratory pressure plates, and spectra of *Nova Geminorum.*

Up to the time of her resignation on April 1, Miss Renner was engaged with the work in photographic photometry. 178 plates made for the investigation of the distance correction and for the determination of the magnitudes of the stars of the Polar Sequence were measured by her. She also devoted much time to the extensive reductions and calculations involved in the photometric investigations.

Miss Sheldon has divided her time between work relating to the physical laboratory, to solar spectra, and to photographic photometry. Of the plates measured, 52 are of laboratory spectra and 89 relate to photometry. The remainder, including a large number, are of solar magnetic fields. Many of these were measured in duplicate, with different measuring instruments. Miss Sheldon has also determined the screw errors of several comparators and has given much time to miscellaneous computations, recording, etc.

Miss Smith has continued her work upon spectroheliograph plates. This has included the determination of the areas of the calcium flocculi upon 254 negatives, thus completing the reductions to March 20, 1912. The curves showing the fluctuations of the areas have been drawn to October 1911. Miss Smith has measured, in addition, 146 prominence plates, completing the reduction of this series to January 1, 1912, and has made 496 prints of negatives of calcium and hydrogen spectroheliograms.

Miss Ware has continued during the year her measures and reductions of solar and laboratory spectra obtained by Mr. St. John. These plates, of which about 150 have been used, were made for the purpose of testing the accuracy of the plane grating when employed for the determination of standard wave-lengths, and for the derivation of the wave-lengths of tertiary standards. The publication of the first results of this investigation has been made jointly by Mr. St. John and Miss Ware.

The library has remained in charge of Miss Haines. The accessions of bound volumes during the year number 733, of which 470 were acquired by purchase, 211 by binding, and 52 by gift. The total number of bound volumes now in the library is 2,550. Miss Haines has also assisted with the editorial work of the Observatory.

INVESTIGATION OF THE PHOTOGRAPHIC PROCESS.

Modern astrophysical work makes unusual and exacting demands upon photography, not wholly satisfied by the plates and the methods of development now available. The small light intensities active in the registration of faint stars and in the photography of spectra of high dispersion require plates of the highest attainable speed; the differentiation of delicate detail on planetary surfaces and in nebulæ and the separation of close spectral lines require plates of strong contrast and fine grain; the investigation of special spectral regions, such as the infra-red, the blue-green, and the extreme ultra-violet, for which the ordinary emulsions of the silver haloids are not highly sensitive, necessitates plates specially treated with optical sensitizers. Any improvement in any one of these particulars—speed, grain, color sensitiveness—would increase correspondingly the efficiency and scope of astrophysical work. One has but to consider the question of speed alone, and from the single standpoint of efficiency, to appreciate the importance of such improvements. With a telescope or spectrograph practically all of the time that the instrument is in use may be spent in the actual exposure of

photographic plates, for with the faint lights involved the exposure time is by far the greater part of that required for all the various manipulations. Doubling the speed of the plate, therefore, practically doubles the amount of work that may be done with a costly instrument. Economic considerations alone would accordingly seem to require that every effort be made to secure improvements, while the increase in efficiency in the broader sense of being able to extend investigations into fields not now accessible is a reason that speaks for itself.

In order to obtain some idea of the present status of photographic manufacture and of the possibility of a further perfection of plates and processes, Mr. Seares has recently interviewed various photo-chemists and manufacturers both in the United States and in Europe. The results of this investigation may be summarized as follows:

The photographic industry has been developed by empirical methods to an even greater degree than most other industries, for the processes involved are among the most obscure in the whole range of physical chemistry. Even to-day there is no agreement among those best informed as to what actually takes place when the emulsion is ripened, or when the ripened and highly sensitive emulsion is exposed to the action of light. Nor is it understood why the emulsification of silver bromide in gelatine leads to a far more sensitive plate than can be obtained through the use of collodion. The chemistry of development is better understood, but even here there are many obscure points.

In the absence of more definite knowledge of these fundamental phenomena it seems clear that plate manufacture must remain the art that it is to-day, and that improvements will be more or less a matter of chance. On the other hand, even a partial solution of the problem of ripening probably would afford a basis for a rationally directed inquiry after improved methods.

As for the more specific possibilities in the way of improvement, the following may be stated: The sensitiveness of the emulsified silver salt depends upon the absorption of the light which falls upon it. Without such absorption there can be no beginning of the action which with the application of a developing agent ends in the reduction of the salt to metallic silver. Apparently the relatively unstable molecules of the silver salt may be regarded as resonators. Ripening renders the molecules more susceptible to the disruptive action of the vibrations to which they are attuned. In practice this seems invariably to be accompanied by an increase in the size of the particles or grains suspended in the emulsion. Whether or not this result is necessary is at present uncertain, though it is certain that a coarse-grained emulsion does not necessarily possess high sensitiveness.

It is significant, however, that the application of various dyes increases, without any increase in the grain, the sensitiveness of the ripened emulsion for wave-lengths for which normally it possesses no special sensitiveness.

The addition of the dye increases the resonance effect for the vibrations in question, but the grain remains unchanged. There seems no *a priori* reason, therefore, why it should not be possible to start with a relatively fine-grained emulsion, and through the addition of a properly chosen substance increase the absorption for those rays for which it is primarily sensitive—the blue and the violet—to such an extent as to make it comparable in sensitiveness with the ordinary high-speed, coarse-grained plate. There seems to lie in this direction an avenue for profitable research, and apparently it possesses the advantage that such investigations need not wait for the solution of the extremely difficult problem of ripening.

The investigation of developing agents also offers a field for investigation, for it is by no means clear that the last word has been said in this connection. It is perhaps too much to hope for a discovery comparable with that of the method of alkaline development, but undoubtedly improvements bearing directly upon the sensitiveness and the grain of the plate are still to be made.

It is a matter of common experience that plates of high speed are lacking in contrast. They solarize without attaining high density. This, however, seems to be a result of the coarseness of grain rather than of the speed. Simple geometrical considerations show that the covering power or density attainable with a given emulsion must depend directly on the fineness and distribution of the particles of reduced silver, and apparently the solution of the problem of preparing rapid plates of fine grain will bring with it the high contrast desirable for many lines of astrophysical investigation.

As already suggested, sensitiveness for special regions may be derived by staining the emulsified silver salt with dyes which cause the molecules to absorb those rays for which sensitiveness is required. We are already in the possession of a combination of dyes well adapted to the production of a general spectral sensitiveness for the entire visible region in the plate most commonly used. This requires modification to adapt it to other types of plate used for various investigations; and it is highly important that a special search should be undertaken for dyes which will bring the infra-red and the extreme ultra-violet more easily within the range of photographic reproduction. Efforts should also be made to reproduce, and improve if possible, the methods used by Abney thirty years ago for the preparation of the red-sensitive emulsions with which he was able to photograph farther into the infra-red than has since been possible.

The above are but a few of the various questions that require study. Numerous others might easily be added, such, for example, as the properties of different kinds of gelatine and of emulsifying media other than gelatine; the conditions which determine the accidental and at present apparently uncontrollable differences in sensitiveness shown by emulsions prepared by the same formula; and the preparation of emulsions with various combinations of the silver haloids, particularly the bromide and iodide of silver.

CONSTRUCTION DIVISION.

The work of construction, though still delayed in the case of the 100-inch reflector, has been active in several departments during the past year. The Director, aided by Mr. Adams, has been in general charge of all construction, and has devoted much time to questions of design. Mr. Ritchey, since his return to the Observatory on January 1, after an absence of three months on account of illness, has had immediate charge of the optical work on the 100-inch mirror. Mr. Drew has carried forward the design of the 100-inch mounting, while the detailed drawings of the dome have been made by Messrs. D. H. Burnham & Co., of Chicago. Mr. Jones has continued his supervision of building construction in Pasadena and on Mount Wilson, and Mr. Ayres has remained in charge of the instrument shop. Mr. Pease, in conjunction with various members of the staff, has designed a large number of instruments and accessory apparatus.

THE 100-INCH TELESCOPE.

The long delay in the construction of the 100-inch reflector, occasioned by the difficulty of casting a suitable glass disk for the mirror, has not been without some compensating advantages. The opportunity has been utilized to make extensive studies of the best type of mounting and dome, and to undertake various supplementary investigations, which may have an important bearing upon the final success of the telescope. It is evident that any considerable improvement in photographic processes, such as an increase in the sensitiveness of plates without a corresponding increase in the size of the silver grains, would have the effect of adding to the efficiency of the instrument. In the same way the improvement of auxiliary apparatus, such as the optical parts of the spectrograph to be used with the telescope, would mean more and better observational results. A great additional gift to the Carnegie Institution of Washington by Mr. Carnegie, accompanied by an expression of his hope that provision would be made for the 100-inch telescope, has rendered possible a general study of these and other questions upon which the efficiency of the telescope depends.

In the matter of design, some difficult questions have presented themselves. Mr. Ritchey favored the adoption of a modified Cassegrain type of reflector, of a form similar to that first suggested by Schwarzschild, in which a large field is obtained by the use of mirrors of special figure. For the photography of nebulæ and other work requiring a large field of good definition, such a plan is very attractive, especially in view of the short and compact tube required for the mounting. But two important considerations seemed decisive: It is highly desirable to be able to work in the principal focus of the 100-inch mirror, to avoid loss of light and possible distortion of field and exaggerated change of focal length due to change in the figure or position of the auxiliary mirror. In fact, we plan to make the greater part

of the observations with the 100-inch in this way. This would not be possible if the modified Cassegrain were adopted, as no real image is obtained unless the two mirrors are used in combination. Again, it is equally important that the telescope be available for use, in the ordinary Cassegrain form, with equivalent focal lengths ranging from 100 to 300 feet, and in the coudé form, for high dispersion photography of stellar spectra with a long-focus spectrograph. The modified Cassegrain would not be available for either of these purposes. In short, while it appears to be a very promising instrument for certain classes of work, it has not the flexibility which may be regarded as essential in the case of the 100-inch telescope. Moreover, as the tube is to be made in sections, its length can easily be reduced in case it should ever become desirable to transform the 100-inch into a telescope of the modified Cassegrain type.

Another plan advocated by Mr. Ritchey was the use of a cylindrical wind-screen, open at the top, in place of a dome. During the day the telescope was to be maintained at a constant temperature within a house which could be rolled away at night, thus affording the advantage of observing in the open air. At first sight this arrangement appeared very attractive, but on further consideration it was abandoned in favor of a dome. It was evident that the proposed wind-screen would not protect the telescope from eddy-currents, and that the inner wall and floor of the drum would be heated by the sun in summer and covered with ice and snow in winter. After long study of shelters of various types, a dome of special construction has been decided upon, and the detailed design has been worked out in accordance with our indications by Messrs. D. H. Burnham & Co., of Chicago. This decision was not adopted, however, until temperature measures in the dome of the 60-inch reflector had convinced us that no disturbance of definition need be feared from the heating of the dome covering, provided that suitable precautions be observed in the design and ventilation of the structure.

The open wind-shield was at first discarded in favor of a dome lined with cork, protected from the sun by a ventilated sheet-metal screen, and maintained at the night temperature throughout the day by a large refrigerating plant. In this connection we are under special obligations to Director Stratton and Dr. Buckingham, of the U. S. Bureau of Standards, for a valuable report on the problems presented by such a dome, prepared by Dr. Buckingham. With sufficient insulation, there appeared to be no difficulty in accomplishing the desired results, but the great cost of construction and the heavy annual expenditure for power were formidable objections. Fortunately, the success of the plan of controlling the figure of the cœlostat and second mirrors of the 150-foot tower telescope by constant-temperature water-jackets, pointed to a new and simple procedure, involving much less expense, both for first cost and maintenance. It is true that this plan does not provide for maintaining the interior of the dome during the day at the night temperature and some difficulty from heating of the air, perceptible under the finest at-

mospheric conditions in so large an instrument, might possibly be feared. But, as already stated, experiments in the dome of the 60-inch show that there is no cause for apprehension on this score, and improvements in the new design will certainly eliminate any outstanding difficulties. Furthermore, in the new plan all the mirrors (and the tube, if necessary) are to be kept at a constant temperature throughout the day and night, thus preventing such changes of figure as would certainly have occurred if the mirror had been exposed to the ordinary fluctuations in temperature of the night air.

All of these considerations will be of no moment, however, unless a suitable 100-inch mirror can be made. In the last annual report it was stated that the French Plate Glass Company had failed in all of its attempts to cast a disk free from internal flaws, and that accordingly the disk sent to us some years ago was being ground to a spherical figure, in the hope that optical tests might prove it to be suitable for use in the telescope. Mr. Ritchey's illness unfortunately prevented him from resuming work until January 1, but the fine grinding was continued without other interruption than that involved in the installation of a ventilating and heating system, with water-spray air-filter and thermostat control, in the 100-inch optical shop. For the work of polishing, it became necessary to make a polishing tool 100 inches in diameter to supplement the smaller tools.

As soon as an approximately spherical surface had been obtained, a regular series of optical tests was begun, with the mirror hanging on edge in a thin, heavily cushioned steel band. Effects of astigmatism were observed, which seemed to vary in magnitude when different diameters of the disk were vertical. The observed effects are so complicated that no satisfactory explanation can yet be given. Among them may be mentioned astigmatism of the surface, apparently not permanent in amount; flexure, different along different diameters, when the glass is turned on edge for testing, and change of figure caused by the daily variation in temperature of the optical shop (about 2° C.).

On August 20 a 36-inch plane mirror was suspended at 45° above the 100-inch mirror, permitting the latter to be tested for astigmatism while lying horizontal. A long series of determinations of radius of curvature, made with the greatest precautions on two days, showed the surface to be slightly astigmatic. The maximum difference of radius of curvature, for two diameters (x and y) of the glass at right angles to each other, was 0.06 inch ($x > y$). When the glass was hung on edge with the x diameter vertical, the radius of curvature of the x diameter was 0.025 inch greater than that of the y diameter. With the y diameter vertical, the radius of curvature of the x diameter was 0.137 inch greater than that of the y diameter. Since the date of the last tests about two-thirds of the astigmatism has been removed.

The changes in figure due to variations in the temperature of the optical room could probably be eliminated by the use of a suitable constant-temperature cell. However, if clear evidence of irregular flexure persists after

the figure of the horizontal mirror has been made truly spherical, it may perhaps become necessary to discard the disk. As the French Plate Glass Company, after repeated trials, has failed to cast a 100-inch disk of the desired thickness (13 inches), a new furnace of different design may be required to give a successful result. An alternative plan, which also appears promising, is to try an excellent 100-inch disk, about 7 inches (18 cm.) thick, which is now at St. Gobain. This showed considerable flexure in a series of accurate tests, very kindly made for us by the Count de la Baume Pluvinel, but a suitable support system would probably eliminate difficulty from this source.

Although we feel confident that a thoroughly satisfactory 100-inch mirror will ultimately be available, it has not seemed wise to begin the construction of the mounting or dome while the present uncertainty exists. After an inspection of the works of the Fore River Shipbuilding Company and a full discussion with their engineers of the design, a contract has been made with this firm to build the mounting on a percentage basis. The drawings have received much study, and are so far advanced that work can be undertaken as soon as the question of the mirror is settled.*

WORK OF THE INSTRUMENT SHOP.

The most important new work undertaken during the year is a large ruling machine for diffraction gratings. As already mentioned, it is essential to the complete success of the 100-inch reflector that its accessory apparatus should be no less perfect than the telescope itself. For this purpose, and also for use with the spectrographs of the two tower telescopes, the Snow telescope, the 60-inch reflector, and the physical laboratory, gratings of large size, and sometimes of special design, are required. Although we are indebted to Michelson for some excellent gratings of large size, and to Anderson for smaller ones of great perfection, we are as much in need of a ruling machine as we were of grinding and polishing machines for specula before our optical shop was equipped with them. As soon as the ruling machine becomes available, many special experiments now out of reach will be rendered possible.

Fortunately, it was not necessary to intrust this very difficult undertaking to untried hands. Through the cordial cooperation of President Remsen and Professor Ames, of Johns Hopkins University, Dr. J. A. Anderson has been granted a year's leave of absence for work in Pasadena. The detailed drawings of the machine have been made by Mr. Pease in accordance with Dr. Anderson's plans and after a careful study of the Rowland engine, which had been completely rebuilt under his direction. Dr. Anderson arrived in Pasadena September 10, and the work will be pushed forward as rapidly as its rigorous requirements permit.

* Since the above was written, the cause of the change of figure observed when the mirror is rotated has been discovered and eliminated. There is now every reason to believe that the present mirror will prove suitable for use in the telescope.

The instrument shop, which has been operated at its full capacity, has constructed the following instruments and accessories during the year:

Focal plane spectrograph, mounted on new cage, for the 60-inch reflector.

Concave grating spectrograph, with interferometer attachment, also for the 60-inch reflector (not yet completed).

Completion of 75-foot spectrograph, including collimator and camera slits; polarizing apparatus; guiding, focusing, and centering devices; comparison arc; mountings of lenses, prisms, gratings, and mirrors, and their installation; liquid prism (in part); hoisting mechanism; repairs to motors, etc.

Completion of 150-foot tower telescope, including mountings and focusing scales for objectives; water-jackets, tanks, and thermostat for controlling the temperature of the mirrors, and their installation with circulating pump, motor, and piping; reduced speed of elevator, and minor repairs.

Large measuring machine for plates 8 by 20 inches.

Six small measuring machines (five unfinished).

An 8 by 10 plate carrier for 60-inch reflector.

Installation of a 500-volt electric generator with alternating-current driving motor and a 17 kw. direct current generator with 25-horsepower alternating-current driving motor, in addition to much minor work on instruments and accessories, for the physical laboratory.

Apparatus for the optical shop, including edge bands and supports for testing the 100-inch mirror; testing frame and truck for 60-inch plane mirror; 100-inch polishing tool, with supporting and driving device; 36-inch polishing tool, with adapter for driving; knife-edge support and testing screw, with photographic attachment; resurfacing grinding tools.

Accessories and repairs of 60-inch reflector mounting and dome, as mentioned above.

Patterns for large ruling machine and for mounting of 10-inch portrait lens telescope.

PASADENA OFFICE BUILDING.

From the beginning of the Observatory's work, our appropriations have been used mainly for instruments and working equipment, while the members of the staff have contented themselves with small and simply furnished offices. As these were insufficient in number, and occupied space in the shop buildings greatly needed for other purposes, a grant was requested last year for an adequate office building, of fireproof construction. Erection was begun in December, on a lot having a frontage of 100 feet, adjoining the instrument-shop building on the east, after plans by Myron Hunt, architect. The building, which is of concrete and brick, with roof of Spanish tile, is now nearly ready for use. The first and second floors are devoted almost exclusively to offices, 30 rooms being provided for the members of the observing staff and the computing division. The library, 24.5 by 36.5 feet, is on the main floor. Underneath is a small stack room and a general laboratory. The basement also contains a plate-storage room 43 by 21.5 feet,

completely fireproof. In this room the heliomicrometer will also be mounted. Adjoining are a dark room and a room 13 by 34 feet, for the study of the photographs. A special instrument shop, for the work of precision done by Mr. Jacomini, chief instrument-maker, occupies the west end of the basement. Beneath it, under conditions especially favorable for constancy of temperature and stability, is a sub-basement for the ruling machine.

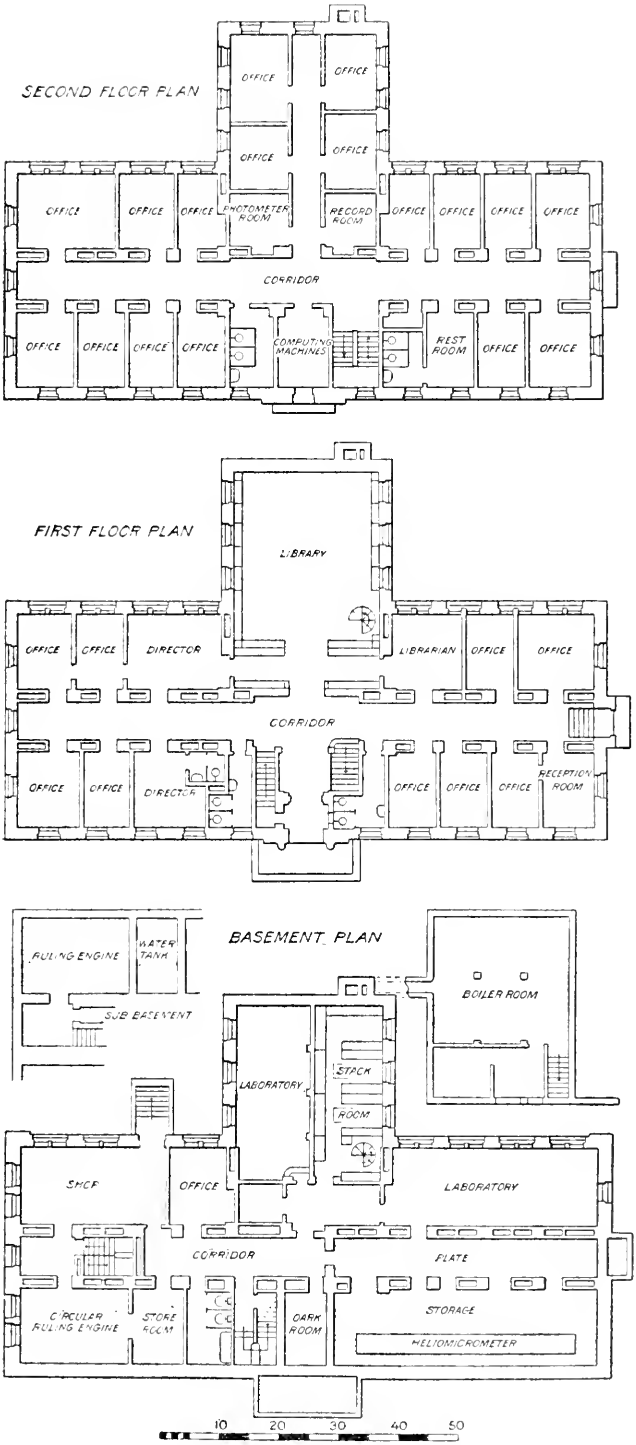
The very complete heating and ventilating plant is in a small separate building below grade to the north. The arrangements for providing a constant supply of pure air to every room, warmed in winter and cooled in summer by passing through a water spray, will be heartily appreciated by the members of the staff.

CONSTRUCTION WORK ON MOUNT WILSON.

Some of the most important construction work of the past year has centered about the power-plant and the distributing system on the mountain. During the winter a 50-horsepower Fairbanks-Morse gas-engine was installed, together with a direct-connected generator of 40 kw. capacity. They have now been in operation for several months and have proved most satisfactory, providing ample power for heavy construction work as well as for the regular requirements of the Observatory. The 25-horsepower engine previously employed has been put in efficient condition for use in emergencies, and may be run in connection with the larger engine when an exceptionally great amount of power is required. An auxiliary dynamo, or "booster," has been added to the equipment for the purpose of regulating accurately the voltage of current used in charging the storage battery. With the probable exception of storage-battery capacity, the power-plant is now capable of meeting the demands of the erection and operation of the 100-inch telescope.

The increasing requirements of the 60-inch reflector in the way of electrical connections has led us to install a large switchboard in the basement of the building, and to transfer to it all of the control switches. This has added greatly to the convenience of operation of the telescope and has centralized in a valuable way the complex distributing system connected with the instrument. The switchboard and automatic control switches were built entirely by the Observatory engineer.

During the past winter some trouble was experienced from the effects of frost on the water-main which extends from Strain's Camp to the reservoir. Accordingly during the summer the line has been relaid at a depth well below the frost level. In view of the greatly increased capacity available through the completion in 1911 of the 140,000-gallon reservoir, it seemed desirable to replace the original 1.5-inch pipe with a 2-inch pipe. The original pipe has been employed as a conduit for the power circuit which operates the electric pump at Strain's Camp and is laid in the same trench with the water line. A very important advantage of this system is that the power line, and consequently the pumping-plant, can not be crippled by a forest fire between the Observatory and Strain's Camp.



Pasadena Office Building.

In order to provide for the gradually increasing requirements in the way of water-supply development, work will be begun this autumn on the well at Strain's Camp. It seems probable, in view of the character of the springs supplying this well, that a sufficient supply may be obtained by an adequate increase in the size of the storage capacity of the well.

An important piece of work during the summer was the construction of a permanent metal screen on the exterior of the 60-inch telescope dome to replace the canvas hitherto used. On account of heavy snow and wind storms we have not found it possible to leave the canvas screen on the dome throughout the winter, and in its absence the air inside the dome (on clear days) becomes considerably heated on account of the direct exposure of the metal roof to the sun's heat. This results in air-currents and some impairment of the definition. It is hoped that the metal screen will be completed before the beginning of the rainy season.

The exterior of the Snow telescope house has been painted during the summer and a few alterations have been made in the sheet-iron louver sections. A steel gutter surrounding the entire building has been added and a portion of the floor at the southern end of the telescope-house has been replaced.

At the request of the Smithsonian Institution the Observatory has erected a 40-foot steel tower above the laboratory building on Mount Wilson, in which Mr. Abbot and his associates have carried on their investigations of the solar radiation. The tower is similar to the 60-foot tower of the Observatory, and may be used in the same way to support a cœlostat and lens in case it is desired to make studies of the radiation of different portions of the sun's disk. An inclined track 160 feet long, supported on trestle-work and provided with a small car and hoisting windlass, has been installed above the Smithsonian laboratory in order to facilitate the transportation of heavy instruments and building materials.

A motor stage, operated in connection with the Mount Wilson Hotel, now runs daily between Pasadena and Mount Wilson, making the trip to the summit in 2¼ hours and the return trip in 1½ hours.

NUTRITION LABORATORY.*

Francis G. Benedict, Director.

With the gradual accumulation of apparatus, both purchased and constructed, the facilities of the laboratory for carrying out projected researches are becoming increasingly valuable, and a larger proportion of time may now advantageously be devoted to research rather than to construction. With apparatus as complicated as is much of that in the laboratory, continual alterations and betterments are to be expected, and all the resources of the laboratory shop are brought to bear upon these important alterations. Coincidently the staff of trained assistants is becoming more and more effective, and additions to it are made yearly. The division of funds for the construction of new apparatus, researches in pure physiology, and pathological investigation still remains one of the most important administrative problems.

ADDITIONS TO EQUIPMENT.

For the most part the work of the laboratory is now following well-organized lines, and the adjustment of the work to the building and, *vice versa,* the adjustment of the equipment of the several laboratories to the work, have progressed to such a stage that relatively few major alterations are to be expected. The two balconies added to the calorimeter laboratory have proved most helpful in making use of this large constant-temperature room. Of especial interest is the fact that during the experiment on prolonged fasting with a human subject the second balcony was utilized as the living quarters of the man when he was not inside one of the respiration chambers. Owing to the construction and isolation of the balcony, it was possible to secure complete control and thus avoid the possibility of the surreptitious taking of food. A balcony has also been added to the room set apart for a psychological laboratory in order to provide more space for psychological research.

ALTERATIONS IN THE RESPIRATION CALORIMETERS.

As the result of experimental work during the past year, alterations have been made in the respiration calorimeters, and notable changes introduced in methods and accessory apparatus. Unfortunately, the elaborate self-recording device installed with the hope of securing graphic records of temperature differences of the water entering and leaving the calorimeter chamber proved to be wholly unreliable and the manufacturers have been unable to guarantee

* Situated at Boston, Massachusetts. Grant No. 748. $45,417 for investigations and maintenance during 1912. (For previous reports on work in nutrition see Year Books Nos. 2–10.)

its successful operation. No satisfactory substitute therefor has as yet been found. By the introduction of a highly accurate psychrometer and modified methods of sampling the air inside the respiration chamber, and by making use of the remarkable gas-analysis apparatus devised by Dr. Klas Sondén, we have been able to rearrange completely the routine for conducting experiments with this apparatus, thereby increasing both the accuracy and the facility of operation and decreasing the cost. A simple but very important modification in the bed calorimeter is the suspension of the bed on knife-edges and a stout spiral spring in such manner as to give exact graphic records of the degree of restlessness of the subject during the experiment. These records have proved invaluable in the interpretation of many of the experimental results.

TREADMILL.

A respiration chamber especially designed for severe muscular work was mentioned in a previous report, and its construction has proceeded regularly though slowly since that time. While connected with the laboratory staff a few years ago, Mr. E. H. Metcalf designed a treadmill for use with man which has recently been constructed, tested, and found most satisfactory. This treadmill consists of a wide leather belt passing over two pulleys, the belt being further supported by a large number of steel tubes with ball bearings in each end. The apparatus has proved most efficient, runs with a minimum amount of noise, and should prove a most valuable adjunct in studying the motion of forward progression, the work of ascent and descent, and similar physiological problems.

RESPIRATION APPARATUS.

The number of researches which can be carried out satisfactorily with the small respiration apparatus devised in this laboratory has been found to be so great that several additional apparatus were constructed. Important modifications recently introduced permit a more extensive use of this method, inasmuch as pathological cases may be studied, thus giving greater value to the results obtained. By the addition of a very lightly counterpoised spirometer, graphic records of the character, amplitude, and volume of each respiration are secured. A simple device also makes possible the accurate record of the total volume of air passing through the lungs. A number of clinicians have been experimenting with this apparatus and pronounce it of very great value.

MODIFICATION OF THE APPARATUS FOR EXPERIMENTS ON SEVERE MUSCULAR WORK.

In connection with the research undertaken by Dr. E. P. Cathcart, of Glasgow, during the past winter, it was necessary to modify somewhat the respiration apparatus to permit accurate measurements of the enormous vol-

umes of carbon dioxide produced and oxygen consumed with a man working at the limit of human endurance. The apparatus was finally so adjusted that it was possible to measure accurately the consumption of oxygen and the carbon-dioxide production during work of such severity as to result in the production of nearly 3 liters of carbon dioxide per minute. By means of a Zuntz mouthpiece and a tension equalizer, consisting of a rubber diaphragm, the large respiration volume common in muscular work could be provided for easily without distressing the subject.

MISCELLANEOUS EQUIPMENT.

A large spirometer for the special study of ventilation with the different types of valves and for determining lung-volume has been devised by Mr. Carpenter and recently constructed.

Owing to the increase in the number of researches on the metabolism of animals, it has been necessary to add to the equipment of the laboratory three metabolism cages for small animals, the design being that of Prof. Hans Meyer, of Vienna.

The bicycle ergometer, which has proved of great value in studying the metabolism of man during excessive muscular work, has been extensively used this winter in Dr. Cathcart's research. It has also been carefully calibrated, and with the cooperation of Prof. W. G. Cady, of Wesleyan University, Middletown, Connecticut, the distortion of the magnetic field by the rapidly rotating copper disk was measured. The apparatus has now several well-determined constants which increase its value greatly.

In preparation for the psychological measurements which will be made later in connection with the metabolism experiments, a full equipment of apparatus has been ordered, including the apparatus devised by Prof. Raymond Dodge, of Wesleyan University, several string galvanometers, and photographic registration apparatus.

The equipment of the chemical laboratory has been added to the past year by the installation of a large-sized electrically driven centrifuge.

The chemical laboratory has also been equipped with a complete set of the apparatus required for the methods of urine analysis recently devised by Prof. Otto Folin, of the Harvard Medical School. These methods promise to revolutionize the technique of urine analysis and are of great value in many other biochemical problems. Through the kindness of Professor Folin, Mr. H. L. Higgins, of the laboratory staff, has been trained in the use of the methods, and they have been employed in this laboratory for several months.

FIREPROOF PROTECTION OF RECORDS.

The multiplication of valuable records made it necessary to secure some simple means of fireproof protection. Although the building is as a whole fireproof, a local conflagration is always possible, and the safe originally installed has long since been outgrown. All of the experimental records,

library cards, abstracts of scientific articles, kymograph records, and similar destructible material that can not readily be replaced have been stored in fireproof steel filing cabinets during the last year. A similar cabinet has been placed upon one of the balconies in the calorimeter room for records that are referred to daily.

ADDITIONS TO THE LIBRARY.

Although it is not the intention to acquire a large library, the most important journals containing articles continually referred to have been purchased from time to time, and back numbers of the journals used by the masters of physiology and physiological chemistry are being gradually accumulated. The value of the library has been much increased by the addition of a full set of the invaluable Index of the Library of the Surgeon General of the Army. The recent volumes of this important series were secured through the kindness of Senator W. Murray Crane.

Of especial importance is the extensive collection of reprints, which has been added to in great number. In the last five years our collection of reprints has increased to over 2,200 separates, almost all of which were presented to the Laboratory. Inasmuch as these are nearly all selected papers bearing particularly upon problems of nutrition and metabolism, they of themselves make a very effective working library.

COOPERATING AND VISITING INVESTIGATORS.

Dr. E. P. Joslin and his associate, Dr. F. A. Stanwood, have continued their active interest in the researches on the metabolism of diabetics.

Dr. John Homans has completed the research on the metabolism of the hypophysectomized animals, and preliminary investigations upon the carbohydrate tolerance of animals have been made.

The metabolism of normal babies has been studied by Dr. Fritz B. Talbot, who has supplemented the observations made in the Nutrition Laboratory by an extensive series of pulse-rate observations made in one of the hospitals in the city.

The researches on dogs with part or whole of the pancreas removed, which were begun last year by Dr. Joseph H. Pratt, have not yet been completed. As slight changes were to be made in the apparatus so as to secure accurate determinations of the oxygen consumption, it seemed desirable to discontinue these experiments until the fall of 1912.

With a view to broadening the significance of the metabolism measurements made in the experimental work of the Laboratory, preliminary steps have been taken to institute researches on the psychological effect of the ingestion of food and of nutritive processes in general. In making these arrangements we have been peculiarly fortunate in securing the cooperation and advice of Prof. Raymond Dodge, of Wesleyan University, Middletown, Connecticut, who has developed a remarkable technique and devised apparatus for experiments of this nature.

Prof. H. M. Smith, of Syracuse University, has spent considerable time in the Nutrition Laboratory, acquiring the technique of respiration experiments, and as a result has instituted a series of observations in Syracuse University on the metabolism of athletes, employing one of the respiration apparatus belonging to this laboratory. The research is well under way and promises interesting results.

Prof. W. G. Anderson, of Yale University, was at the laboratory two weeks acquiring the technique of gas-analysis with the Sondén and Haldane gas-analysis apparatus.

Dr. David L. Edsall, of the Washington University Medical School, recently appointed Professor of Clinical Medicine at the Harvard Medical School, spent a good part of the winter in the laboratory, studying with a small respiration apparatus, paying particular attention to the effect of altered respiration types upon the carbon-dioxide elimination. The graphic records secured by Dr. Edsall and the amounts of carbon dioxide simultaneously measured have suggested many important problems in this field. Dr. Edsall made this research the basis of his Shattuck lecture, "The clinical study of respiration," delivered before the Massachusetts Medical Society, June 11, 1912.*

Dr. Paul Roth, of the Battle Creek Sanitarium, Battle Creek, Michigan, has devoted several weeks to a study of the methods used in this laboratory for determining the respiratory exchange, with a view to making important investigations upon the metabolism of vegetarians. Dr. Roth's extraordinarily skillful technique and thorough understanding of problems of this nature insure a most valuable study of the metabolism of those persistently living upon a non-flesh diet.

Prof. C. C. Benson, of the Department of Household Science, University of Toronto, Toronto, Canada, spent the summer at the laboratory, thoroughly familiarizing herself, under the direction of Mr. Thorne M. Carpenter, with the construction and technique of the respiration apparatus. She conducted a large number of individual experiments, bearing in mind particularly the problems in connection with her work on women at the University of Toronto. A respiration apparatus of the latest type used in this laboratory is soon to be constructed at the University of Toronto, and the experimental work carried out with it promises to add materially to the data regarding the metabolism of women.

RESEARCH ASSOCIATE.

The Executive Committee of the Carnegie Institution of Washington appointed Dr. E. P. Cathcart, Grieve Lecturer of Physiology in the University of Glasgow, as Research Associate attached to the Nutrition Laboratory for the academic year 1911–12. Dr. Cathcart's previous experience in meta-

* Boston Medical and Surgical Journal, p. 639, Nov. 7, 1912; Proceedings Mass. Medical Society, 1912.

bolism made his visit to the laboratory of great value to us. He occupied himself during the winter with an extended series of researches on the effect upon metabolism of very severe muscular work. With a professional bicycle rider as subject, experiments were made nearly every day throughout the winter upon the character and the amounts of metabolism during severe muscular work. During his sojourn here we profited much by Dr. Cathcart's keen analytical criticism of manuscripts and of problems continually arising in the laboratory.

INVESTIGATORS ASSOCIATED IN RESEARCH ON PROLONGED INANITION.

In connection with a study of prolonged inanition on a Maltese gentleman, who volunteered to come to the laboratory as a subject, we have enjoyed the cooperation of Dr. H. W. Goodall, who made most careful clinical examinations throughout the fast; Prof. W. G. Anderson, of Yale University, who made the anthropometric measurements, assisted by his son, Mr. W. L. Anderson; Dr. H. S. Langfeld, of Harvard University, who made a daily series of psychological tests, and a number of the faculty of the Harvard Medical School, including Dr. J. E. Ashe, who devoted himself to an examination of the blood; Prof. E. G. Martin, who studied the subject's sensibility to electric shock; Dr. A. I. Kendall, now of Northwestern University, who made a bacteriological examination of the feces, and Professors E. E. Southard and Otto Folin, both of whom offered valuable suggestions. Indeed, it was only by the cooperation of all of these gentlemen that the success of the study was made possible.

STAFF NOTES.

After two years of successful chemical experimentation in this laboratory, Dr. A. W. Peters resigned his position as chemist to accept the position of biochemist of the Vineland Training School for Feeble-Minded Children, Vineland, New Jersey. During his connection with the Nutrition Laboratory he developed a number of methods for the exact determination of copper and of reducing sugars.

Mr. J. C. Bock, of Vienna, formerly of the department of chemistry of the Michigan Agricultural College, has recently been added to the staff of the laboratory as chemist. His initial work in the laboratory is the analysis of the urines collected in the research on inanition, with special reference to the ash and mineral constituents. To fit himself especially for this work, he was accorded the privilege, through the courtesy of Dr. Rufus Cole, of spending several weeks at the hospital of the Rockefeller Institute for Medical Research, acquiring, under the direction of Dr. Francis H. McCrudden, the technique developed in their laboratory for such analyses.

To aid in the administrative details of the laboratory, a special appointment has been made of Mr. W. F. O'Hara as administrative secretary, and in the future much of the routine work which has fallen upon the Director

and Mr. T. M. Carpenter will be assigned to Mr. O'Hara, who will devote his entire time to this work.

INVESTIGATIONS IN PROGRESS.

METABOLISM DURING PROLONGED INANITION.

The most extensive single research undertaken in the laboratory in the past year has been a study of prolonged inanition on A. L., a native of Malta, who volunteered to come to this country and subject himself to a long fast. The plans for a fast had been developing for some years following the completion of the research on inanition carried out with the aid of a grant from the Carnegie Institution of Washington at Wesleyan University, Middletown, Connecticut. When the final arrangements were completed for the arrival of the subject, practically the whole staff of the laboratory was concentrated upon this study. The subject slept every night in the bed calorimeter, thus securing on the average 11 to 12 hours' of continuous measurements of heat, carbon-dioxide production, oxygen consumption, water vaporization, body temperature, pulse-rate, and respiration-rate. During the day he was subjected to numerous tests with the respiration apparatus, and extensive investigations of the composition of the blood, clinical examinations, microscopical and complete chemical examination of the urine, psychological tests, and anthropometric measurements. An extensive series of photographs was also made from week to week which shows the changes in weight and the degree of emaciation. A most interesting series of X-ray photographs was taken by Dr. Francis H. Williams, of the X-ray department of the Boston City Hospital, at the end of inanition. The subject continued for 31 days without food, drinking only distilled water. The laboratory staff will be occupied for several months in making the complete analyses and the computations of the results of the experiment. The material is now being prepared for publication and will shortly be published by the Institution.

METABOLISM AS INFLUENCED BY SEVERE MUSCULAR WORK.

Owing to the enthusiastic cooperation of Dr. E. P. Cathcart, 1911–12 Research Associate of the Institution attached to this laboratory, a long series of observations was made on a professional bicycle rider with regard to the influence of prolonged and excessive muscular activity upon the character and the amounts of metabolism. Using a modified form of respiration apparatus, Dr. Cathcart was able to secure definite information with regard to the alterations in the character of the metabolism during work, and likewise studied the total metabolism as indicated by the measurements of the amounts of oxygen consumed and the carbon dioxide produced. By means of a carefully calibrated bicycle ergometer, it was possible to draw deductions with regard to the mechanical efficiency of man. These results are now being prepared for publication.

METABOLISM IN DIABETES MELLITUS.

Although most of the year was occupied in the computations of earlier researches in this line, opportunity was had to study one particularly interesting case of diabetes, and a most careful series of experiments was made on this subject. The results are incorporated in a report on diabetes mellitus, Publication No. 176 of the Carnegie Institution of Washington.

COMPARISON OF METHODS FOR DETERMINATION OF THE RESPIRATORY EXCHANGE.

This research, which was begun by Mr. T. M. Carpenter, of the laboratory staff, has been prosecuted during the spring and summer months. In connection with this investigation comparisons were made of the following apparatus:

(1) The bed calorimeter, with the Benedict respiration apparatus developed in this laboratory. This portion of the comparison has extended over several years, and a large number of experiments have been made, the two apparatus being used on the same day so as to secure results more strictly comparable. In this comparison both the older and later types of respiration apparatus were used.

(2) The older form of the Benedict respiration apparatus, employing a rubber diaphragm, with the later type in which a spirometer is used. The experiments were made with subjects without breakfast, *i. e.,* after at least 12 hours' fast, these being alternated in a series, or a series of experiments carried out with one apparatus, and a subsequent series made on the other. A comparison of nose and mouth breathing has also been made with this apparatus, using both the earlier and later forms.

(3) The Zuntz apparatus and the Benedict respiration apparatus. In some experiments with the former, the Zuntz gas-analysis apparatus was used, and in others the Haldane gas-analysis apparatus. In connection with this comparison, collection of the gas samples was made both over water and over mercury. Various types of valves, also the nosepiece and the mouthpiece, were used.

(4) The Tissot apparatus with the Benedict respiration apparatus. In this comparison the Tissot spirometer, Chauveau valves, and the glass nosepieces were used, both the nosepiece and mouthpiece being employed.

(5) The Douglas method of determining the respiratory exchange was also tested, two sizes of bags being used for the collection of gas, different types of valves, and both the mouthpiece and the nosepiece.

For studying the ventilation of the lungs with different types of valves, a specially constructed spirometer was used; from this study has resulted a respiration apparatus of the closed-circuit type, using a spirometer and valves, with calcium chloride as the absorbent of water.

In connection with the study of nose-breathing *vs.* mouth-breathing, a modified form of the Tissot glass nosepiece has been constructed. In studying the different types of respiration, a lead mask with a molding material on the edge of it has also been used. In all of these comparisons the pulse-rate, the respiration-rate, the respiratory exchange, and the volume of respiration were obtained on subjects lying quietly at rest.

Mr. Carpenter's extended experience in various laboratories and his unique technical skill have made it possible for him so to compare all the methods that the results are convincing and open to little, if any, criticism on the part of the various investigators in this field.

METABOLISM OF INFANTS.

Projected alterations in the respiration apparatus whereby determinations of oxygen will be secured have delayed somewhat active experimentation on the metabolism of infants. A few experiments have been made during the past year, and in the fall the research will be continued. The striking relationship between pulse-rate and the gross metabolism was evident in infants but a few weeks old.

INFLUENCE OF THE HYPOPHYSEAL SECRETION UPON THE SUGAR TOLERANCE OF ANIMALS.

Basing his research upon the important observations of Goetsch, Cushing, and Jacobson, Dr. Homans has begun a preliminary series of experiments on animals, studying the effect of the hypophyseal secretion upon the sugar tolerance. These experiments, which were proceeding in a most satisfactory manner, were interrupted by Dr. Homans's tour in Europe.

INFLUENCE OF DECREASED ABSORPTION ON THE METABOLISM FOLLOWING INGESTION OF FOOD.

The interesting observations made in connection with Dr. Joseph H. Pratt on dogs with disturbed pancreatic secretion which exhibited a markedly different reaction to the ingestion of protein have been supplemented by a series of observations on two other dogs. The research was necessarily interrupted while the apparatus for determining oxygen with animals was being developed.

INFLUENCE OF THE INGESTION OF FOOD ON METABOLISM.

For many years evidence has been accumulating in this laboratory with regard to the influence of the ingestion of food upon metabolism. Many of these experiments were made with the respiration calorimeter in Wesleyan University, Middletown, Connecticut, and they have a certain fundamental significance. Later investigations, however, have shown that more sharply defined results can be obtained by means of the newly devised respiration apparatus, and hence the earlier work is being in part repeated and verified with this apparatus. The greater part of the work has been completed and

is now being prepared for publication. The investigation and its suggestive ramifications should lead ultimately to an adequate explanation of the phenomena of increased metabolism following the ingestion of food.

NORMAL METABOLISM OF MEN AND WOMEN.

Measurements of the metabolism of normal men and women are secured by Mr. L. E. Emmes whenever an opportunity offers in connection with the work in the laboratory. Practically all of the cooperating and visiting investigators have at times volunteered to act as subjects and we are rapidly accumulating a large amount of most valuable data with regard to the influence of bodily activity, body characteristics, height, size, age, sex, and weight upon metabolism. Each year sees a substantial addition to our valuable factors which are continually being used for comparison with pathological cases.

FACTORS AFFECTING THE REDUCTION OF COPPER BY REDUCING SUGARS.

Dr. A. W. Peters has continued his work upon the determination of sugars in diabetic urines, and has made an elaborate study of the factors influencing the reduction of copper in alkaline tartrate solution, paying particular attention to the concentration of the solution, the temperature, and the time relations involved in the reaction. This extremely careful study has made clear many obscure points in the use of the well-known solutions of Fehling and Allihn for the determination of sugar by the reduction of copper. Much of the empiricism of the older methods has now been replaced by accurate scientific manipulation.

PUBLICATIONS.

The following publications have been issued or are in press:

(1) The metabolism of the hypophysectomized dog. Francis G. Benedict and John Homans. Jour. Med. Research, 25, p. 409. 1912.

This research, which has been in progress for two or three years, involved the measurement of carbon-dioxide production, body temperature, pulse-rate, and records of muscular activity of animals before and after the removal of the hypophysis. The apparatus for determining the carbon-dioxide production is described in detail and consists of modifications of the small respiration apparatus regularly in use with man in this laboratory, a chamber being attached when measuring the total carbon-dioxide production of animals. The movements of the animals are recorded graphically by means of a cage suspended on a knife-edge, using the motions of a pneumograph to transmit air-pulsations to a tambour which writes upon a smoked paper drum. The relationship of the carbon-dioxide production, pulse-rate, and the muscular activity as recorded on the drum is very striking. The general effects of hypophysectomy as here studied were: a tendency to retard the normal growth of the animal, the gain in weight being due principally to the deposition of fat; a slightly lower body temperature, which may result ultimately in a disturbance of the heat regulation suf-

ficiently profound to produce a marked drop in body temperature immediately prior to death; a notable decrease in the pulse-rate a few days after operation, the pulse-rate then remaining at essentially the same level throughout the life of the animal; a similar fall in the respiration rate; and a decrease in the total metabolism as measured by the carbon-dioxide production, the fall in carbon-dioxide production per kilogram of body-weight per hour being still more noticeable owing to the deposition of inert body-fat. With young animals the growth is checked and their infantile characteristics are preserved; the sexual activity, if not already developed, never develops, and if nearly or quite established it is profoundly affected. The tendency to the deposition of an excessive amount of body-fat is sometimes accompanied by a thickening of the skin and falling of the hair analogous to changes noticed after thyroidectomy. The change in appearance of older animals surviving a nearly complete removal of the hypophysis is hardly noticeable.

(2) The influence upon metabolism of non-oxidizable material in the intestinal tract. Francis G. Benedict and Louis E. Emmes. Amer. Jour. Physiol., 30, p. 197. 1912.

The early observation that when food passes through the alimentary tract there is an increase in the energy requirement of the body has received several explanations. Of these the one strongly supported by Professor Zuntz and his scholars is that the mechanical movements of the intestinal tract in the digestion of foods is the primary cause of this increase in metabolism. This conception was strongly substantiated by a series of observations made by Loewy in the Zuntz laboratory on the effect of a dilute solution of sodium sulphate, which provoked a powerful peristaltic effect and, according to Loewy's experiments, resulted in a very greatly increased metabolism. The importance of this fundamental explanation of the increase in metabolism due to food ingestion called for a repetition of these experiments with modern technique and with greater care as to the control and registration of the extraneous muscular activity of the subject. The experiments were made with the small respiration apparatus used in the Nutrition Laboratory, graphic records were made of the muscular activity, the pulse-rate was continually recorded, and ideal subjects were used. The ingestion of 15 grams of crystallized sodium sulphate in 200 c.c. of water resulted in a powerful peristaltic action, but in no increase in the carbon-dioxide excretion or oxygen consumption, nor was there any measurable increase in general of the pulse-rate. The inference is that when suitable precautions are taken for the control of the extraneous muscular activity, the ingestion of sodium sulphate, notwithstanding the intense peristalsis, does not materially increase the gaseous metabolism of the body as a whole.

On the supposition that an intestinal activity involving segmentation rather than powerful peristaltic waves might result in a larger metabolism, the subjects were given varying amounts of agar-agar which produced voluminous stools and obviously called for more mechanical work through the process of segmentation. In the ideally controlled experiments there was no measurable increase in the carbon-dioxide output or oxygen intake.

It appears, therefore, from the results obtained in this series of experiments, that although the movements along the intestinal tract of a bulky material such as agar-agar, taken either in jelly form or with water, is accomplished without the expenditure of any considerable or measurable amount of energy, yet the "work of digestion," in so far as either peristalsis or segmentation is concerned, can not be of sufficient moment to play an

important rôle or to determine in any degree the marked rise in metabolism so frequently noted after the ingestion of various food materials.

(3) The influence on the respiratory exchange of varying amounts of carbohydrate in the diet. Francis G. Benedict and Harold L. Higgins. Amer. Jour. Physiol., 30, p. 217. 1912.

The character and amount of body metabolism before food is consumed in the morning (*i. e.*, after active digestion has ceased) is dependent to large extent upon the character and amount of the diet on the preceding day. This paper gives the results of a study of the effect on the respiratory exchange of variations in the carbohydrate content of the diet of the preceding day. It was observed that the same diet, with the same individual, always led to essentially the same respiratory exchange the next morning before food was taken; also with different normal individuals the same diet led to essentially the same respiratory quotient, showing that similar body material was being metabolized. Daily diets were calculated having a constant protein content (105 grams) and a constant energy value (3,000 calories) but varying amounts of carbohydrates (100, 125, 200, 400, and 600 grams respectively), the fat content being regulated to make the required energy content of the diet. A carbohydrate-free diet was also used. The average respiratory quotients following diets with varying amounts of carbohydrates are given in the table.

When little or no carbohydrate had been taken, the respiratory quotient is seen to approximate conditions indicating the combustion of pure fat (respiratory quotient 0.71), while with larger amounts of carbohydrates in the diet the respiratory quotient was nearer that for carbohydrates alone (respiratory quotient 1.00). The conclusion is drawn that the supply of body carbohydrate bore a distinct relation to the quantity of carbohydrate in the preceding diet. For determining the respiratory metabolism, use was made of the small respiration apparatus devised in this laboratory.

Diet No.	Carbohydrate.	Respiratory quotient.
	gms.	
1	0	0.71
2	100 }	.75
3	125 }	
4	200	.80
5	400	.82
6	600	.86

(4) The sources of error and the electrolytic standardization of the conditions of the iodide method of copper analysis. Amos W. Peters. Jour. Amer. Chem. Soc., 34, p. 422. 1912.

The conditions were determined for the standardization and use of sodium thiosulphate when intended for the measurement of copper, especially in sugar analyses. A method was devised for the rapid electrolytic deposition of copper by simple means with the use of a tartrate-cyanide electrolyte; also a general method for the preparation of solutions of metallic copper or of its compounds for the iodide method. It was shown that the results by the iodide method are affected by varying concentrations of mineral acid and by the presence of salts with or without acetic or mineral acid, and how these effects can be compensated quantitatively. The conditions of accuracy of the iodide method were determined for both sugar analysis and for general purposes.

(5) A critical study of sugar analysis by copper reduction methods. Amos W. Peters. Jour. Amer. Chem. Soc., 34, p. 928. 1912.

This paper, which embodies the examination of the iodide method of copper analysis elaborated in the previous paper, involves a study of the various

volumetric methods for the determination of copper in alkaline tartrate liquids. The needs of this laboratory for the accurate and rapid determination of sugar in urine are such as to demand especial technique. After a series of experiments in which were studied the process of reduction, the standardization of the heating power, and the influence of changes in time and temperature upon the reduction, conditions were so controlled that a series of constant tabular values for the reducing power of pure dextrose were obtained. The research was characterized primarily by the quantitative standardization in detail of the conditions of reduction, and of the volumetric estimation by the iodide method of the copper in alkaline tartrate solutions. The method has been applied with good results to the determination of the reducing power of urine as well as other physiological materials.

(6) Ein Universalrespirationsapparat. Francis G. Benedict. Deutsch. Archiv f. klin. Med., 107, p. 156. 1912.

Since the original description of the respiration apparatus devised in this laboratory was published in 1909, many alterations have been made in the apparatus which adapt it not only for experiments with men but also, by the addition of different types of respiration chambers, for experiments with infants and animals; it is accordingly now designated "a universal respiration apparatus." This paper includes an elaborate presentation of all the technique in the actual use of the apparatus, and describes some new features which have been added with particular reference to studying the mechanics of respiration. It also describes in detail a method for measuring the oxygen consumption by means of a meter, and methods for testing the apparatus for tightness, and shows its adaptation to experiments with severe muscular work and to experiments with animals or infants. A description of the method of calculating the results, together with the presentation of data obtained from several experiments, completes the paper. The normality of the results is shown by a comparison of the experimental values obtained on this apparatus with those obtained with the bed calorimeter when the subjects are lying quietly, breathing without any special respiratory requirement. This paper, which represents the first complete description given in a foreign language, was written primarily to assist many European investigators in this field who are now planning to use the apparatus in their researches.

(7) The composition of the atmosphere with special reference to its oxygen content. Francis G. Benedict. Publication No. 166, Carnegie Institution of Washington. 1912.

The marked change in composition of the air as it passes through the lungs is of great value in estimating the character of the combustion processes in the body. For a quantitative understanding of these processes, an exact knowledge of the composition of the outdoor air is essential. The first part of this publication consists of an extensive review of earlier literature and a history of air-analysis. The present-day view of the composition of the air is well summed up by F. W. Clarke,* who says:

"In a roughly approximate way it is often said that air consists of four-fifths nitrogen and one-fifth oxygen, and this is nearly true. The proportions of the two gases are almost constant, but not absolutely so; for the innumerable analyses of air reveal variations larger than can be ascribed to experimental errors."

* Data of Geochemistry, U. S. Geological Survey Bul. 330, 1908, p. 38.

In the second part of the report is given a description of an accurate gas-analysis apparatus devised by Dr. Klas Sondén, of Stockholm, together with the technique of its use and the results of a series of analyses of outdoor air covering nearly three years, which were made by Miss Alice Johnson in the Nutrition Laboratory. The steps in the elimination of individual errors in the technique and routine are carefully traced until finally the conclusion is reached that uncontaminated outdoor air in Boston is of constant oxygen content, irrespective of conditions of weather, humidity, temperature, barometer, wind direction, etc. Further analyses of air taken from many points on the Atlantic Ocean and from the top of Pike's Peak showed a like uniformity in composition. The average results of all the analyses made in this research of outdoor air are summarized in the table presented herewith:

	No. of analyses.	Carbon dioxide.	Oxygen.*
		p. ct.	*p. ct.*
Air near laboratory	212	0.031	20.952
Ocean air (Montreal-Liverpool)	7	....	20.950
Ocean air (Genoa-Boston)	36	....	20.946
Pike's Peak	9	....	20.941

* In water and carbon dioxide-free air.

(8) A bicycle ergometer with an electric brake. Francis G. Benedict and Walter G. Cady. Publication No. 167, Carnegie Institution of Washington. 1912.

A form of stationary bicycle in which the rear wheel is replaced by a copper disk rotating in an electro-magnetic field has been extensively used in this laboratory for measurements of the mechanical work of man. Certain important calibration tests, friction measurements, and particularly the peculiar magnetic reaction produced by the copper disk rotating between the poles of the magnet, are described in this publication. Two instruments were used, one having been calibrated several years before. The new calibration of this latter instrument showed essentially the same values as the earlier tests. The speed usually assumed by a bicycle rider ranges from 60 to 90 revolutions per minute, and at these speeds the ergometer, singularly enough, gives essentially the same heat per revolution. At slower and higher speeds there is a marked decrease in the heat per revolution. A careful study of the magnetic reactions in the disk showed the peculiarly interesting demagnetizing effect of the eddy current in the disk. The research has led to many theoretical as well as practical deductions.

(9) Some fundamental principles in studying infant metabolism. Francis G. Benedict and Fritz B. Talbot. Amer. Jour. Diseases of Children, 4, p. 129. 1912.

With a modified form of the universal respiration apparatus used in this laboratory and designed for studying the metabolism of infants, a research has been carried out to determine the metabolism from the carbon-dioxide production. A portion of the results are presented in this paper. Especial care was taken to secure a continuous record of the pulse-rate by means of a Bowles stethoscope attached to the chest of the infant, and in addition a graphic record of the minor muscular activities of the sleeping child, to determine their relationship with the metabolism. For the purpose of supplementing these records, a number of observations were made in two Boston hospitals of the pulse-rate of babies at various times of the day. The wide fluctuations in these records, even during periods of sleep, are shown

in a series of curves. The record of a single experiment with a baby is given in the table herewith.

Baby 5. Record 2.
November 16, 1911.
Weight naked, 7.6 kilos.
Age, 7½ months.

Period.	30-minute periods.	
	Pulse per minute	Carbon dioxide per 30 min.
		gms.
1	117	3.49
2	108	2.73
3	113	2.97
4	122	3.24
5	117	3.33
6	130	3.41

The graphic record accompanying this test showed that the pulse-rate and the carbon-dioxide production were very closely identified with the muscular activity as indicated on a kymograph drum.

In conclusion the authors state:

"Although the results of our investigations on the whole are not yet ready for publication, we feel convinced of the importance of considering in all subsequent metabolism experiments the pulse-rate of the infant, and particularly the degree of muscular activity. The enormous variations in the total metabolism as affected by what might otherwise appear to be slight muscular activity are such as to lead us to question seriously all experiments made in 24-hour periods, and we wish to assert that all metabolism experiments on infants made without known controlled pulse-rates and without graphic records of muscular activity are lessened enormously in value by the absence of these important factors."

(10) A study of metabolism in severe diabetes. Francis G. Benedict and Elliott P. Joslin. Publication No. 176, Carnegie Institution of Washington. 1912. (In press.)

Since the publication of the earlier results of the investigation on diabetes mellitus (Publication No. 136 of the Carnegie Institution of Washington), a considerable amount of research has been carried out with especial reference to the metabolism in severe cases of diabetes. The results of the later investigation are reported in this publication, and include experimental data regarding 17 cases, 6 of which were also studied in the earlier part of the research. Of these 17 cases, all but 3 are classified as "severe diabetes." The apparatus and methods used were substantially the same as those previously employed, except that the sugar in the urine of the diabetics was determined by an improved method which was specially devised by Dr. A. W. Peters for the purpose; a description of this method is given.

In this later investigation the attempt was made to study the individual cases more systematically and completely, at least three of the cases being carefully observed over a considerable period of time. The clinical history of each case is given, with complete details of the experiments. The pulse-rate, body-temperature, body-weight, nitrogen excretion, and gaseous metabolism are discussed in some detail, considerable attention being given to body-weight. Since loss of weight is a marked feature of diabetes, and these changes should be interpreted intelligently, the fluctuations in body-weight of normal individuals are considered at some length; a comparison is also made of the body-weights of the diabetic subjects in health with those in disease, and data given regarding the loss in weight of some 200 diabetics. To obtain evidence as to whether or not the metabolism is increased in diabetes, the results secured with the individual subjects are compared with the data found in experiments with one or more normal individuals who were comparable in body-weight and height. Comparisons are also made of the metabolism of diabetics with varying degree of severity and under varying conditions as to the intensity of the acidosis, thus giving

opportunity to study the relationship between the severity of the diabetes and the degree of increased metabolism. Further evidence is supplied by a study of the influence of an experimentally induced acidosis upon the metabolism of a normal individual, experiments being made with two subjects when a carbohydrate-free diet was given.

As a result of these investigations, the conclusion is drawn that the metabolism in diabetes is increased above the normal about 15 per cent, thus confirming the conclusion given in the first report. The authors also believe that there is a close relation between the intensity of the metabolism and the severity of the disease, this being indicated not only in the comparison of the metabolism in light cases of diabetes with that in severe cases, but also in the comparison of the metabolism of the same individual with varying degrees of acidosis, and by the fact that normal individuals on a carbohydrate-free diet showed an increase in metabolism.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

The operations and chief results of the Department during the period November 1, 1911, to October 31, 1912, in brief were:

CONTINUATION OF THE MAGNETIC SURVEY OF THE OCEANS WITH THE AID OF THE NON-MAGNETIC VESSEL, THE "CARNEGIE."

At the end of the last fiscal year the vessel had completed her projected circumnavigation cruise as far as Batavia, Java. She sailed from there on November 21, 1911, bound for the eastern part of the Indian Ocean, and went thence to Manila, Philippine Islands, where she arrived on February 3, 1912; the total distance covered on this leg of the cruise was 8,292 miles and the time at sea was 75.5 days. The cruise continued from Manila to Suva, Fiji; thence to Papeete, Tahiti, from which port the *Carnegie* sailed on October 15, bound for Coronel, Chile. It is expected that the present circumnavigation cruise will be completed by the end of 1913. The total distance covered during the present fiscal year will be about 28,000 nautical miles; the magnetic declination was determined at about 260 points along the tracks of the vessel, and the magnetic dip and intensity at about 180 points.

The errors in the charts of the lines of equal magnetic declination used by mariners, as disclosed by the observations on board the *Carnegie* in the eastern part of the Indian Ocean, reached nearly the same magnitude as those found in the western part of this ocean, viz, 3° to 5°, according to the chart used; the errors were again systematic. However, in the China Sea and that part of the Pacific Ocean between Manila and Suva the chart errors in magnetic declination have been gratifyingly small, usually less than 1°. The latter regions had already been partially covered by the work of our previous vessel, the *Galilee,* and the results of the observations had been supplied to the leading hydrographic establishments. On the passage from Suva to Tahiti the errors in the charts of the lines of equal magnetic declination amounted to nearly 2°.

All the results of observations on board the *Carnegie* of the magnetic element of chief interest to the mariner, the magnetic declination, obtained on her first cruise as well as on her second, up to arrival at Suva on June 7, 1912, have already appeared in print; the results for the passage from Suva

* Address: The Ontario, Washington, District of Columbia. Grant No. 750. $97,810 for investigations and maintenance during 1912. (For previous reports see Year Books Nos. 3–10.)

to Tahiti, up to September 11, 1912, having been received, they will also be published soon.

The maximum errors in the charts of the lines of equal magnetic inclination and of equal horizontal intensity were as follows: In the eastern part of the Indian Ocean, 3.5° in magnetic dip and one-thirtieth part in the horizontal intensity; in the China Sea, 1.5° in magnetic dip and one-fortieth part in horizontal intensity; in the Pacific Ocean between Manila and Suva, 3.5° in dip and one-fourteenth part in horizontal intensity, and between Suva and Tahiti, nearly 8° in magnetic dip for one of the charts and about one-thirtieth part in horizontal intensity. It should be stated that at the date of the issue of the charts in question neither the results of the *Galilee* dip and intensity observations nor those of recent Antarctic expeditions were available.

As the cruise of the *Carnegie* is arranged so as to intersect the paths of the *Galilee* and of other previous expeditions as frequently as possible, valuable secular variation data are also being obtained. The generally systematic nature of the chart errors, as above noted, appear in large measure to be due to imperfect knowledge of the corrections which must be applied if past observations are to be brought up to date.

CONTINUATION OF THE MAGNETIC SURVEY OF LAND AREAS IN REGIONS WHERE THE ACQUIREMENT OF NEW AND ADDITIONAL DATA IS URGENT.

The work during the present fiscal year has been chiefly in Africa, Asia, Australia, and South America, the details of which will be found on pp. 232 to 234. The chief expeditions were led by Dr. C. K. Edmunds in Southern China, Indo-China, and Siam between November 1911 and February 1912; by Mr. E. Kidson in Western and Central Australia, including an overland trip of 1,100 miles by caravan from the railroad terminus, Oodnadatta, in South Australia, to Pine Creek, thence by rail to Port Darwin, on the north coast of Australia; by Mr. W. H. Sligh in Tripoli, Tunis, Algeria, and Morocco, and from the Canary Islands by small boat along the coast of Rio de Oro and Mauretania to St. Louis, Senegal; by Mr. D. W. Berky in Morocco, Sierra Leone, and French Guinea (on October 29 a trans-Saharan expedition, in charge of Mr. Berky, accompanied by Mr. H. E. Sawyer, left Biskra, Algiers, for Timbuktu); by Mr. J. P. Ault's party in Peru, Bolivia, and Chile. There has now been completed a series of stations across the entire continent of South America, beginning at Para, at the mouth of the Amazon, and extending to the Pacific coast at Callao, Peru, via the Amazon and Ucayali rivers and Lima.

The total number of land stations at which the three magnetic elements have been determined during the fiscal year will amount to about 235; at about one-tenth of these stations more or less complete observations had been made previously, and thus data for secular variation will also be obtained.

WORK IN WASHINGTON.

In addition to the final reduction of the field observations, the manuscript was completed of the first volume of researches of the Department containing the results of all land observations made by observers of the Department between 1905 and 1910 at about 1,500 stations. This publication is now in press. The Director has continued his researches on the physical theory of the Earth's magnetic and electric phenomena and has published three papers on the results obtained. Dr. N. E. Dorsey, Research Associate, completed an investigation involving the complete theory of the earth-inductor and the applicability of this instrument to the measurement of the magnetic dip on board the *Carnegie*. As the result of these studies, an instrument was constructed in the workshop of the Department after the design of Messrs. Dorsey and Fleming, and was supplied to the *Carnegie* at Tahiti in September. Under the heading "Shopwork" further information will be found as to the instruments constructed by the Department.

SPECIAL OBSERVATIONS DURING THE TOTAL SOLAR ECLIPSE, OCTOBER 10, 1912.

Besides special magnetic observations by observers of the Department on the day of the eclipse, cooperation was secured from various institutions in North and South America. Furthermore, Prof. Walter Knoche, Director of the Instituto Central Meteorológico y Geofisico de Chile, proceeded from Santiago, Chile, under the joint auspices of his Institute and the Carnegie Institution of Washington, to a station in the belt of totality, in the southeastern part of Brazil, and made atmospheric, electric, and allied observations.

The Director takes this opportunity to acknowledge his indebtedness to the various members of his staff for the work accomplished during the year.

DETAILS OF MAGNETIC WORK DURING THE YEAR.

LAND WORK.

Africa.—Upon completing his work in Italy and Malta, Observer W. H. Sligh made magnetic observations in northern and northwestern Africa, occupying 32 stations in Tunis, Algeria, and Morocco, and 2 stations in the Canary Islands. A number of these occupations gave valuable secular variation data. From the Canary Islands he carried out successfully an unusually difficult and hazardous trip by small boat along the coast of Rio de Oro and Mauretania to St. Louis, Senegal, where he arrived the latter part of July, having determined the three magnetic elements at 10 stations. After observing at 3 stations in French West Africa he went to Algiers, where, during September, he assisted Observer D. W. Berky in his preparations for an expedition across the desert of Sahara to Timbuktu. At the close of the fiscal year Mr. Sligh was still engaged in Algiers.

Mr. Berky joined Mr. Sligh in Morocco at the end of March for instruction and assignment to field work. He made magnetic observations at 6 stations in Morocco and during July and August observed in Sierra Leone and French Guinea at 8 stations. He arrived at Algiers early in September and left Biskra on October 29, in charge of an expedition across the Sahara desert. Observer H. E. Sawyer accompanied and assisted Mr. Berky on this expedition, joining the party at Algiers in September. Special magnetic observations were made at the Algiers Observatory by Messrs. Sligh, Berky, and Sawyer on October 10, 1912.

Asia.—Observer C. K. Edmunds, during November 1911 to February 1912, made magnetic observations in China, Indo-China, and Siam. Four stations were occupied in Yunnan Province, China. The original plan for the extension of the magnetic survey further inland had to be abandoned at Yunnanfu on account of the revolution, then at its height. The program was accordingly changed and work was undertaken in Indo-China and in Siam, 26 stations being secured in Indo-China and 9 in Siam. The observations at Lop Buri, Siam, are of particular interest, as this place is identical with Louveau, where Guy Tachart, S. J., observed the magnetic declination in 1682. Dr. Edmunds was accompanied, as in 1911, by Assistant Observer Ngaan Yen Kwong.

Australasia.—The magnetic work in Australasia during the present year has been continued under charge of Observer E. Kidson. In November and December 1911 he made observations at Mildura, Woomelang, and Melbourne in Victoria, at Hobart in Tasmania, and at Albury in New South Wales. At Hobart the magnetic instruments (in part supplied by the Department of Terrestrial Magnetism) of the Australasian Antarctic Expedition were compared and standardized by simultaneous observations with Mr. Kidson's outfit. Messrs. E. N. Webb and A. L. Kennedy, magnetic observers for the expedition, were further instructed in the use of instruments and methods. While at Melbourne dip intercomparisons were made with the observatory dip circle. In January secular variation data were secured by observations at two stations at Nelson, New Zealand. During February to April complete observations were secured at 25 stations in Western Australia. While at Mount Magnet observations at 5 auxiliary stations were made to investigate in a general way the local disturbance in this locality; the disturbance decreased as the mount was descended and very rapidly so on leaving the actual formation of the mount itself and proceeding along the plain at its foot. Arriving at Adelaide, South Australia, about the middle of May, Mr. Kidson set out on a transcontinental trip to Port Darwin. On May 24 his party arrived at Oodnadatta, the northern terminus of the railroad; from this point travel northward to Pine Creek, the southern terminus of the railroad from Port Darwin, was by caravan about 1,100 miles. On July 25 the party arrived at Barrow Creek, about half the journey having been accomplished. The party experienced many

hardships, and the successful execution of the work required no little perseverance, endeavor, and self-sacrifice. It is a pleasure to make record of the substantial assistance rendered by the Australian Post Office Department and the officers of the Overland Telegraph. Port Darwin was reached September 17. The total number of stations occupied in South Australia and the Northern Territory was 40. Upon completion of the work at Port Darwin, Mr. Kidson's party sailed for Melbourne, stopping en route to make observations at Thursday Island; special magnetic observations were made at this station on October 10, 1912, in connection with the solar eclipse of that date. Mr. F. W. Cox served as assistant observer after May and accompanied Mr. Kidson on the transcontinental trip.

Europe.—Having completed his work in Italy in October 1911, Observer W. H. Sligh left Rome on November 1 en route to Africa and made magnetic observations at Palermo (Sicily) and Valetta (Malta). Later, in connection with his work in Morocco, he secured magnetic data at Gibraltar and at San Roque, Spain.

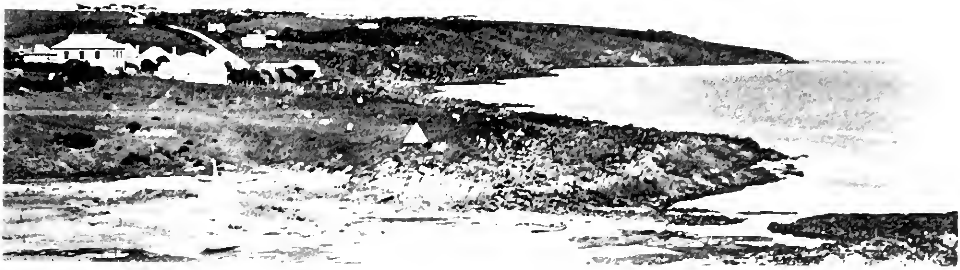
South America.—Magnetic work in South America was begun in April by a party composed of J. P. Ault, chief, and Observers H. R. Schmitt and D. MacKenzie. The magnetic elements were determined at 54 stations in Bolivia, Chile, Ecuador, and Peru. Observer Schmitt carried out a difficult expedition in Peru, starting at Lima and extending to Masisea on the Ucayali River, connecting there with Observer Stewart's work of 1910 and 1911 on the Amazon and Ucayali rivers; one series of stations across the entire continent has thus been completed. Returning to Lima August 17, Mr. Schmitt set out shortly afterward to establish a series of magnetic stations from Lima to Cuzco, where he arrived October 30.

Observer MacKenzie, after observing at 6 stations in Peru and Bolivia, resigned in June and was replaced by Observer A. D. Power. The latter reported to Mr. Ault at Mollendo on July 19 and since then has made magnetic observations at 16 stations along the coast in Peru and Ecuador en route to Venezuela, the region of his future work.

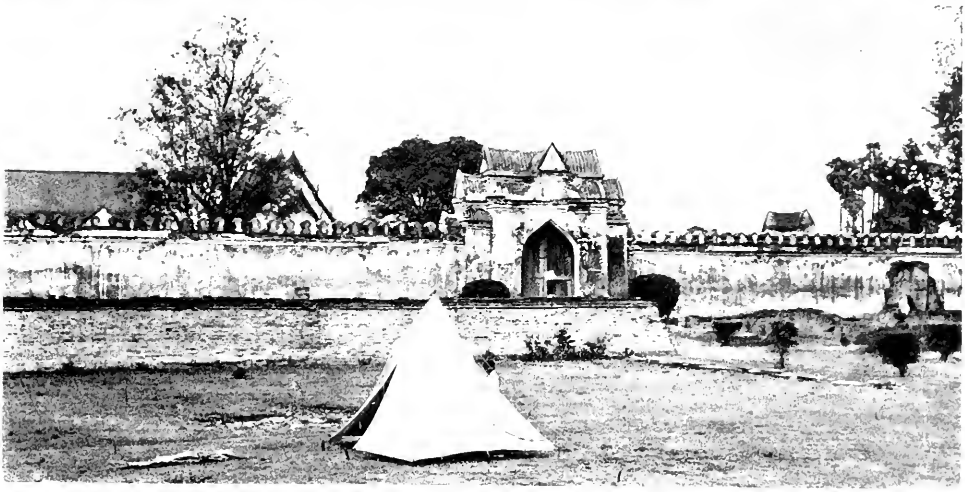
Special magnetic observations in connection with the total solar eclipse of October 10, 1912, were made by Mr. Schmitt at Ayacucho, Peru, and by Mr. Power at Esmeraldas, Ecuador.

Mr. Ault having completed all necessary arrangements for the continuation of the magnetic work in South America by Messrs. Schmitt and Power, left Lima on August 20 and returned to Washington in order to carry out special work in connection with the *Carnegie's* visit to Papeete, Tahiti.

Miscellaneous.—On his way to South America in April, Mr. Ault reoccupied our magnetic station at Colon, Panama. In connection with operations of the *Carnegie,* land stations have been established at Manila, Philippine Islands, where intercomparisons were obtained with the magnetic standards of the Antipolo Observatory; at Suva, Fiji, and at Papeete, Tahiti. These stations will furnish valuable secular variation data.



View of Magnetic Station at Christmas Cove, Kangaroo Island, South Australia.



Magnetic Station at Lop Buri, Siam, near Ancient Palace.

Magnetic Party en route in the Andes, Peru.

INSPECTION WORK.

At the end of the last fiscal year the Director, having completed his final inspection of the work of the *Carnegie,* then at Batavia, Java, began his return to Washington, where he arrived December 24. En route he visited the magnetic observatories and institutions at Hongkong, Manila, Antipolo, Zi-ka-wei, Tsingtau, Tokio, Honolulu, Mount Wilson Solar Observatory, and the Tucson Magnetic Observatory.

OCEAN WORK.

The ocean work of the Department has been continued by the *Carnegie* in the Indian and North Pacific oceans. At the close of the last fiscal year the vessel was at Batavia, Java, from which point, after the necessary shore magnetic observations had been made and the instruments had been intercompared with the standards of the Batavia Magnetic Observatory, she sailed on November 21, 1911, bound for Manila by a circuitous route arranged so as to cover the eastern part of the Pacific Ocean. The course followed was south-southwest in the Indian Ocean to south latitude 30.8° and east longitude 89.4°; thence as far south as 37.5°, in east longitude 95.5°. From this point a general northeasterly course into the China Sea and the North Pacific was followed. The *Carnegie* reached Manila, Philippine Islands, on February 3, 1912, having been out 75½ days from Batavia and covering a distance of 8,292 miles; the conditions for observations were good.

Intercomparisons of instruments were made at the new Manila Magnetic Observatory (situated at Antipolo) with the U. S. Coast and Geodetic Survey standards and with those of the Antipolo Magnetic Observatory. Upon the completion of the land work and of minor repairs in dry dock the *Carnegie* left Manila on March 24, 1912, pursuing a northeasterly course off the Lu Chu Islands, and thence practically due east to north latitude 30° and east longitude 166°. Thence the course was in general southward to Suva, Fiji Islands, where the vessel, after having been considerably delayed by head winds, arrived June 7, 75 days out from Manila; the total distance covered from Manila to Suva was 8,158 miles. The track of the *Galilee* was crossed several times and thus valuable secular variation data have been obtained.

Upon the completion of the land work at Suva, including a reoccupation of the *Galilee* station of 1906, the *Carnegie* left for Papeete, Tahiti, June 30, 1912. The departure was considerably delayed by reason of contrary winds and the difficulties of the narrow passage at Suva. A course was steered along the thirtieth parallel south, passing between the outward and homeward-bound passages of the *Galilee's* last cruise. From near Easter Island a northerly course was followed to the equator; thence the course was westerly, and then southerly to Tahiti. On crossing the equator, the ship

was swung under favorable conditions for dip and intensity. The observations, made on the various headings in the two domes, again showed smaller differences among themselves than the general accuracy of sea observations.

Papeete, the principal port of Tahiti, was reached September 11, 1912; on October 15, after completion of the land work, the vessel sailed for Coronel, Chile.

During the year the *Carnegie,* in the three passages mentioned, has covered 26,997 nautical miles, obtaining 411 magnetic stations at sea, of which 240 were declination stations and 171 were both intensity and dip stations. A general summary of the results is given elsewhere. At the three ports of call the expedition has received most cordial assistance; in particular may be mentioned Dr. W. van Bemmelen at Batavia; Mr. Newton W. Gilbert, Capt. Welker, Father Algué, and Father Sadera Maso at Manila; the Surveyor General, Mr. R. R. Rankine, Harbor Master Captain Wooley, and Mr. Joske at Suva; Mr. Léon Gérand, Gouverneur p. i. des Etablissement français de l'Océanie, and Mr. North Winship, U. S. consul at Tahiti.

Mr. Frary, besides making the chief observations for the ship's position, took part in the magnetic observations, as did also Dr. Edmonds, in addition to his duties as surgeon. The atmospheric electricity observations have been made on board, as opportunity afforded, by Messrs. Johnston and Hewlett, who also participated in the magnetic work.

The vessel continued throughout the year under the direct command of Mr. W. J. Peters. At Papeete Dr. C. W. Hewlett joined the vessel as observer in place of Mr. Frary, resigned. The personnel of the *Carnegie* has otherwise remained the same as last year, except that Mr. M. Meisenhelter joined the vessel at Manila as ship's clerk and meteorological observer and Mr. E. Laursen, first watch officer, succeeded at Manila Mr. F. S. McMurray, resigned.

OFFICE WORK.

The manuscript of the first volume of researches of the Department, giving the results of the land observations since the inauguration of the observational work in 1905 through 1910, has been completed and is now in press. Excellent progress has been made also on the final computations of the ocean observations obtained during the various cruises of both the *Galilee* and the *Carnegie.*

The Director has continued his series of papers in the Journal of Terrestrial Magnetism and Atmospheric Electricity on the physical theory of the Earth's magnetic and electric phenomena.

Dr. N. E. Dorsey was appointed a research associate in the Department on March 16, 1912. He has completed an investigation assigned him involving a complete theory of the earth inductor, considering in detail (1) the various conditions under which such an instrument can be used for the determination of the inclination; (2) the procedure that must be adopted

in order to obtain the most reliable results; (3) the effects of various maladjustments, and (4) the applicability of the instrument for marine work. As the result of this investigation, it was decided to attempt the use of the earth inductor at sea. Accordingly a proper instrument was designed and constructed in the shop of the Department and furnished to the *Carnegie* at Tahiti in September; its operation at sea has proved successful.

Instrumental constants and corrections on the provisional international magnetic standards of the Department have been determined for 7 magnetometers and 5 dip circles. As heretofore, these standardizations have been made by the method of simultaneous comparisons with the standard instruments. Owing to building operations near the site of the testing observatories, this observational work had to be temporarily discontinued early in September. The reductions of the field observations have been kept up to date. General and specific instructions for field and ocean work have been prepared as necessary.

Upon the occasion of the tenth anniversary of the founding of the Institution the Department participated in an exhibit at the Administration Building of the work of the various activities of the Institution, furnishing instruments, charts, and photographs showing the status of the magnetic work. On March 20 the Department also took part in an exhibit of scientific apparatus at the National Museum, given under the auspices of the Washington Academy of Sciences.

The compilation of past magnetic observations, indexing of current literature, and abstracting of publications of special interest have been continued. Requests for information and data have been numerous and varied and have been answered in such detail as has been possible.

Among foreign visitors who have familiarized themselves with the work of the Department may be mentioned Governor E. Schultz of Apia, Samoa; Prof. Carl Störmer of Christiania, Prof. Erich von Drygalski of Munich, General J. de Schokalsky of St. Petersburg, Prof. E. Brückner of Vienna, Prof. E. de Margerie of Paris, Prof. H. Maurer and Prof. F. Jaeger of Berlin, Prof. G. C. Chisholm of Edinburgh, Messrs. H. O. Beckit and A. G. Ogilvie of Oxford, Dr. O. Klotz of the Dominion Observatory, Ottawa, and Prof. Bernhard Weinstein of the University of Berlin.

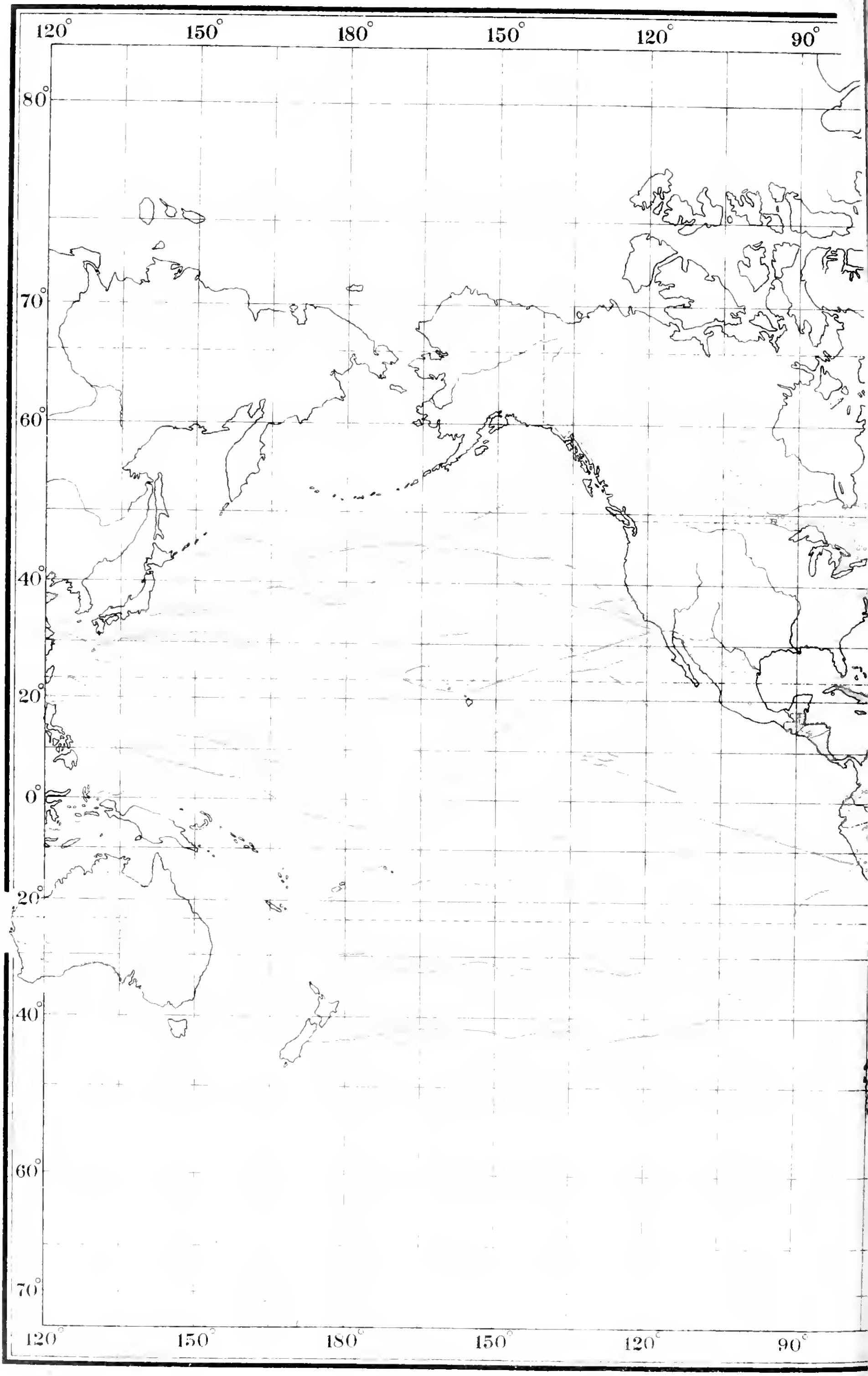
SHOP WORK.

Four universal magnetometers of the 1910 type with some mechanical improvements have been completed. Earth inductor No. 3 as especially designed for use at sea was constructed and forwarded to the *Carnegie* at Tahiti. Owing to the difficulties experienced with the regulation pattern of gimbal stand on account of lack of level and failure to return invariably to the same position, a reversible ball-bearing gimbal stand has been designed and constructed. The knife-edges for this stand have been made of an alloy of platinum and iridium and the bearing surfaces on the gimbal rings are of

agate. It is hoped that this new stand will give increased accuracy in the dip work, as it affords a means of eliminating effects from errors of level. Six theodolite magnetometers of the light portable type are now under construction. A dividing engine constructed by the Société Génevoise was received in December 1911 and installed during January 1912, thus making it possible to construct an instrument practically entirely in our shop. A 16-inch engine lathe has been purchased and added to the tool equipment. The construction of auxiliary instruments and the overhauling and repairing of field outfits have been carried out as necessary.

PERSONNEL.

The personnel of the office force during the year has been as follows: L. A. Bauer, Director; N. E. Dorsey, research associate, from March 16; J. A. Fleming, magnetician in charge of office and shop; H. W. Fisk, magnetician; J. P. Ault, magnetician, to March 21; D. W. Berky, magnetic observer, March 1 to 14; R. H. Galt, magnetic observer, April 1 to September 23; C. W. Hewlett, magnetic observer, June 1 to August 14; D. MacKenzie, magnetic observer, February 21 to March 27; A. D. Power, magnetic observer, May 15 to June 28; H. E. Sawyer, magnetic observer, from July 1; H. R. Schmitt, assistant magnetic observer, January 25 to March 27; J. H. Millsaps, bookkeeper and stenographer; H. D. Harradon, translator and stenographer, from April 7; Emma L. Beehler, stenographer, to March 31, when she resigned; R. R. Mills, clerk, from December 1, 1911; J. A. Widmer, chief instrument-maker; E. K. Skonberg, second instrument-maker; F. R. Sommer, mechanician, from November 1, 1911; J. A. Donaldson, messenger and apprentice, to July 31.



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[Projected cruise of the *Ca*
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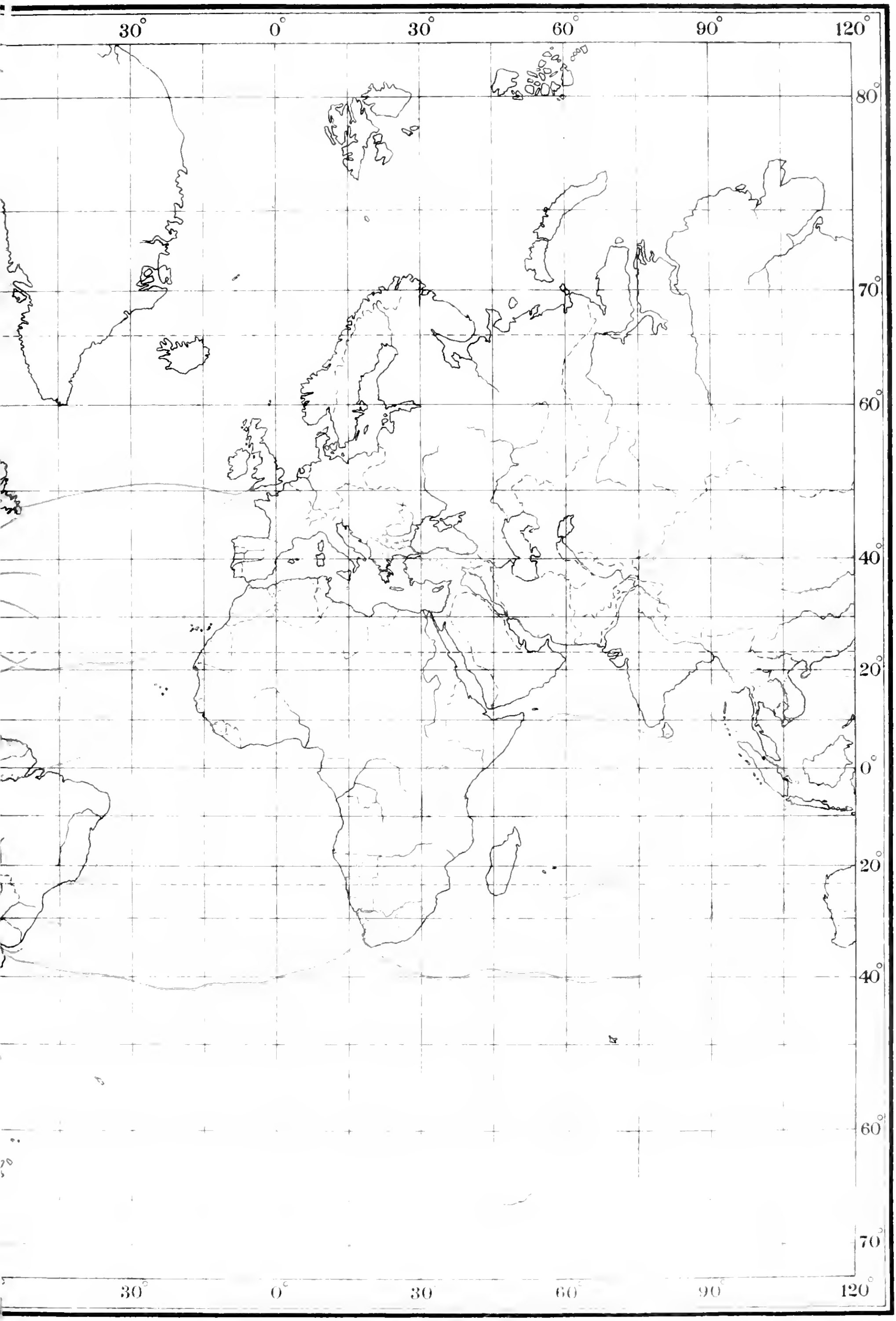

NT OF TERRESTRIAL MAGNETISM, 1905-12.

October, 1912, to October, 1913:
ts and islands of Atlantic Ocean—New York.]

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of the Managing Committee, Columbia University, New York, N. Y. Grant No. 619, allotted May 16, 1910. *Maintenance of a fellowship in architecture at Athens.* (For previous reports see Year Books Nos. 4–10.) $1,200

Mr. William B. Dinsmoor, the fellow in architecture, has followed the same lines in his work that he did last year. He has made great progress in the epigraphical work which bears upon his architectural study, and some of the results of this he will publish in the American Journal of Archæology during the coming winter. He has been able to identify more unrecognized inscriptions and thus materially to advance our knowledge. Mr. Dinsmoor has also carried his studies at Delphi somewhat further, and these have been printed in the Bulletin de correspondance hellénique for the current year.

Brigham, William T., Bernice Pauahi Bishop Museum, Honolulu, Hawaiian Islands. Grant No. 341, allotted January 9, 1906. *Surveying, photographing, and describing the heiau, or ancient stone temples of the Hawaiians, in connection with a treatise on "Ancient Hawaiian Worship."* (For previous reports see Year Books Nos. 5–8.) $2,500

No special expedition under the grant has been undertaken during the year. While Mr. Stokes was on the islands of Niihau and Kauai, engaged in work directly concerning the Bishop Museum, he examined thoroughly the few heiau on Niihau and visited one newly reported on Kauai. Niihau is a small island to the northwest of the Hawaiian group, and is seldom visited by strangers. Mr. Stokes had expected to gather much heiau lore from the natives of the island on account of its seclusion, but on landing it was found that the original inhabitants had gradually become scattered over the other islands of the group since the establishment, between 1860 and 1870, of the present ranch, and that the natives now living there know nothing of the history of the island.

A new phase in structure was observed on Niihau, in the form of a heiau of the luakini class built of blocks of coral sandstone. All large heiau examined elsewhere were built of basaltic blocks.

Dr. Brigham is still engaged in collecting material for his treatise.

Van Deman, Esther B., Rome, Italy. Grant No. 752, allotted December 15, 1911. *Research Associate in Roman archeology.* (For previous reports see Year Books Nos. 9 and 10.) $1,200

The fall and winter months of the year 1911–12 were devoted almost exclusively to the preparation, for publication in a preliminary form, of the canon, or norm, of construction of the concrete monuments in and near Rome. In the course of this work several hundred monuments or parts of

monuments have been examined with respect to (1) their orientation and level; (2) their structural environment, that is, their relation to the buildings adjacent to them; (3) their material and methods of construction. In the formation of the canon only those monuments have been considered for the date of which conclusive evidence exists other than that of construction. In addition to the more general data concerning the type of construction used in these buildings, tables have been compiled showing the exact measurements of one hundred to two hundred typical courses of brick facing of each of the different periods except those of the Antonines, Aurelian, and the late empire, for which the data are as yet incomplete. The main features of the canon, so far as at present determined, have been embodied in two papers published in the June and September numbers of the American Journal of Archæology of the present year. Two papers on the development of brick-faced concrete among the Romans were presented at the Third International Congress of Archæology, which was held in Rome from the 9th to the 16th of October.

The most important among the monuments to which especial attention has been given are the porticus of Lucius and Gaius in the Forum, the domus Aurea of Nero, the forum of Trajan and the amphitheatrum Castrense, and the thermæ of Caracalla, where the extent of the fire of the time of Aurelian and of the restorations following it have been determined. A discussion of the porticus of Lucius and Gaius will appear in an early number of the American Journal of Archæology.

A number of typical concrete structures of unknown or doubtful date have also been examined and classified by the aid of the new canon of construction. The gratifying results obtained warrant the belief that by means of the canon, when completed, the solution of many of the present topographical problems may be rendered possible, as well as the establishment of a more scientific classification of the monuments in general.

In connection with the more special investigation now in hand, data are being collected (1) for a series of plans (arranged chronologically) of the more important sections of the ancient city, based primarily on the evidence of construction; (2) for a technical description of the individual monuments with respect especially to the materials and methods of construction.

During the year a week was spent at Frascati in the general examination of the remains of the republican villas in that vicinity and of Tusculum. Two weeks were devoted to a comparison of the types of construction used at Pompeii with those of Rome. As a result of this preliminary examination, it is clear that the methods of construction used in Pompeii, even under Roman rule, retained much of their earlier Greek character. A few days were spent in Ischia in the search for traces of the famous brick industry located there in Roman times. Valuable evidence was discovered incidentally bearing upon the question of the site and history of the Greek city of Pithecusa. With the kindly cooperation of Commendatore Vaglieri, Director

of Excavations at Ostia, a systematic study has been begun of the extensive concrete monuments laid bare by the recent excavations, which, on account of their agreement in type with those of Rome, are of especial importance in the present investigation.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. Grant No. 779, allotted December 15, 1911. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–10.) $12,500

At the completion of volume IX of the Index Medicus (1911), Dr. Robert Fletcher resigned his position as editor in chief, on account of his advancing years, as expressed in the following notice inserted in the Index Medicus for January 1912:

> Over thirty years ago I was associated with Dr. John S. Billings, U. S. Army, in the devising and publication of the Index Medicus, a journal unique in its plan and method of issuance. The state of my health warns me to withdraw from this engrossing editorial work, and my connection with it ends with the completion of the volume for 1911.
>
> It is with unalloyed satisfaction that I leave the Index Medicus in the charge of Dr. Fielding H. Garrison, who has been for many years my able co-editor.

In connection with the above, I desire to state that such ability and experience as I have for the duties devolving upon me are largely due to the careful and rigorous training in bibliography which I have received at Dr. Fletcher's hands and to the advantages which I have derived from his wise counsel and superior scholarship during the fifteen years of my association with him.

The Index Medicus for 1911 is a volume of 1,357 pages, exclusive of the annual index, making an advance of 132 pages over the volume for 1910. As the output of medical literature seems continually to increase, the question of limiting the selection of material for the monthly number will naturally suggest itself at some future time. In spite of this increase, these numbers have been issued with greater promptitude of late and it is hoped that the Annual Index may be published next year before the end of June.

No changes have been made in the monthly scheme of classification, which has stood the test of time. On account of the remarkable increase in recent literature bearing upon physiology and pathology of the ductless glands, special places have been made for these subjects under appropriate rubrics.

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 762, allotted Dec. 15, 1911. *Continuation of the study of tautomerism and catalysis.* (For previous reports see Year Books Nos. 4–10.) $2,000

Work on tautomerism and catalysis has been continued with the cooperation of the collaborators named below.

During the past year the studies on catalysis and the mechanism of organic reactions have reached the point where it seems certain that both ions and nonionized substances may be concerned in many chemical changes.

On the mechanism of organic reactions. By S. F. Acree. Amer. Chem. Jour., 48, 352.

As a further contribution to our theory that in all reactions we should consider the possibility of the direct transformation of both ions and nonionized substances, the writer presents in this article work by his collaborators, Dr. H. C. Robertson, Dr. E. K. Marshall, Dr. Julia Peachy Harrison, Dr. J. Chandler, Dr. Sidney Nirdlinger, Dr. F. M. Rogers, Miss B. Marion Brown, and Mr. J. H. Shrader, on the reactions of alkyl halides with sodium, potassium, and lithium ethylates, with sodium, potassium, and lithium phenolates, and with sodium phenylurazole. In all of these cases it has been found that the alkyl halide reacts with both the *nonionized salts,* such as *nonionized* sodium ethylate or sodium phenolate, and with the *anion* of the salt, such as the ethylate anion and the phenolate anion.

$$C_2H_5I+\bar{O}C_2H_5 \longrightarrow (C_2H_5)_2O+\bar{I}$$
$$C_2H_5I+NaOC_2H_5 \longrightarrow (C_2H_5)_2O+NaI$$

When both of these reactions are taking place side by side the total reaction must be expressed by the equations

$$\begin{aligned}\frac{dx}{dt}&=K_i\alpha(C_{salt}-x)\ (C_{alkylhalide}-x)\\&\quad+K_m(1-\alpha)\ (C_{salt}-x)\ (C_{alkylhalide}-x)\\&=[K_i\alpha+K_m(1-\alpha)]\ (C_{salt}-x)\ (C_{alkylhalide}-x)\\&=K_v\ (C_{salt}-x)\ (C_{alkylhalide}-x)\end{aligned}$$

When solutions varying in concentration from N/1 to N/32 are used, the simultaneous equations $VK_v=K_n=K_i\alpha+K_m\ (1-\alpha)$ can be used to find the values of K_i and K_m, which are the reaction velocities of a gram ion of ethylate ions, for instance, and a gram molecule of sodium ethylate molecules, in one liter.

Although there is a wide variation in K_n and in α, the values for K_i and K_m are quite constant and give the average $K_i=0.127$ and $K_m=0.0594$, for the reaction of sodium ethylate and methyl iodide. But if this theory is correct we should obtain the same value for K_i for the ethylate ion when we study the reaction of methyl iodide with sodium ethylate and with potassium ethylate, although the values of K_m may differ in the two cases on account of the difference between the two molecules. Potassium ethylate actually gives the same value, $K_i=0.127$, for the ethylate ion, that we obtain from sodium ethylate and methyl iodide. This is especially striking in view of the fact that the *molecular* potassium ethylate, for which $K_m=0.066$ for this reaction, reacts 12 per cent faster with the methyl iodide than does the molecular sodium ethylate.

Still other satisfactory evidence for the theory is the fact that sodium phenolate, potassium phenolate, and lithium phenolate have different de-

grees of ionization in the same concentrations and react with different velocities with methyl iodide, and yet these three salts, in concentrations varying from N/1 to N/32, give the same value for K_i, namely, 0.0282, 0.0283, and 0.0284, respectively. The values of K_m are 0.00474, 0.0037, and 0.0040, respectively, this wide variation harmonizing very nicely with our theory because of the differences in the nonionized sodium, potassium, and lithium phenolates.

Dr. J. Chandler proved, as did also Dr. Sidney Nirdlinger and Dr. F. M. Rogers working together, that ethyl iodide reacts with both the anion and the nonionized portion of sodium phenyl thiourazole in ethyl alcohol at 25°. The solutions were varied in concentration from N/3 to N/64. Dr. Chandler found the values $K_i = 0.465$ and $K_m = 0.16$. Dr. Nirdlinger and Dr. Rogers found the values $K_i = 0.43$ and $K_m = 0.17$ in their work; the solutions contained small quantities of water, which lowers the reaction velocity.

The work of Stieglitz on the catalysis of imido esters has been interpreted unfortunately by him and gives excellent evidence for our theory. We find that *both* the cations and the nonionized salts are decomposed by the molecular water, Stieglitz believing that the cations alone are decomposed and that the water reacts through its ions alone.

The work of Tubandt on the inversion of menthone by sodium ethylate has been recalculated by us and found to give fine evidence that the ethylate anion and the nonionized sodium ethylate are about equally active in this transformation.

The recent work of H. Goldschmidt on the esterification of formic acid, acetic acid, phenylacetic acid, and butyric acid by the catalyzer trichlorbutyric acid, especially in the presence of the aniline salts, shows very clearly that there are esterifications of cations as well as of nonionized complexes taking place.

We are extending the study of these problems to very dilute solutions and hope to measure some of the reactions accurately in N/1000 concentration. In such a case it will be interesting to see whether the above equations hold accurately in all concentrations beyond say N/50, and especially to learn whether 10 or 20 molecules of an added salt change the reaction velocity of a N/500 or N/1000 solution of the reacting salt exactly as is demanded by the above equations. Our evidence seems to show that in such dilute solutions these equations should hold accurately, and that there should be no appreciable "abnormal effect" produced by the added salts. This matter will be decided definitely after further careful studies.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 763, allotted December 15, 1911. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–10.) $1,000

With the assistance of the Institution the following researches were carried on under Professor Baxter's direction:

In order to confirm the value 31.03 (Ag = 107.870) previously found for the atomic weight of phosphorus by the analysis of silver phosphate and phosphorus tribromide (see Year Books Nos. 8 and 10), the preparation of pure phosphorus trichloride and its analysis were undertaken by Dr. C. J. Moore.

The trichloride was synthesized by allowing pure dry phosphorus to unite with a slight excess of pure dry chlorine in a vacuum to avoid contact with air and moisture. The small amount of pentachloride and possible traces of hydrochloric acid were eliminated by fractional distillation in a vacuum, and the remaining material was distilled into a series of small glass bulbs which were individually sealed off while exhausted.

The weight of each specimen of trichloride was found and the analysis, by comparison with metallic silver and by weighing the silver chloride produced, was carried out almost exactly as described in the case of phosphorus tribromide.

Two series of samples were collected by fractional distillation of two different preparations.

In the following table of results a higher number indicates a more volatile fraction, while the lowest number indicates essentially residual material. The atomic weight of silver is assumed to be 107.870.

Number of fraction.	Series I.		Series II.			
	Ratio $PCl_3 : 3Ag$.	Atomic weight of phosphorus.	Ratio $PCl_3 : 3Ag$.	Atomic weight of phosphorus.	Ratio $PCl_3 : 3AgCl$.	Atomic weight of phosphorus.
1	0.424511	31.018	0.424505	31.016	0.319538	31.034
2	0.424505	31.016	0.424505	31.016	0.319515	31.024
3	....	....	0.424510	31.017	0.319520	31.026
4	0.424517	31.020	0.424508	31.017	0.319506	31.020
5	0.424508	31.017	0.424504	31.015	0.319498	31.017
6	....	....	0.424502	31.015	0.319506	31.020
7	0.424508	31.017	....	....	....	....
8	0.424505	31.016	0.424504	31.015	0.319502	31.018
9	....	....	0.424506	31.016	0.319489	31.019
10	....	....	0.424508	31.017	0.319506	31.020
Average	0.424509	31.017	0.424506	31.016	0.319509	31.022

The close agreement of the results of the analyses in each series and of the averages of the different series is the best evidence of the purity of the trichloride. Unless a constant boiling mixture of trichloride and pentachloride exists, the uniformity of the material indicates a high degree of purity.

The three researches upon the atomic weight of phosphorus yield the following values:

	Ag = 107.880.	Ag = 107.870.	Ag = 107.860.
Ag_3PO_4	31.04	31.03	31.02
PBr_3	31.027	31.024	31.021
PCl_3	31.018	31.015	31.012
Average	31.028	31.023	31.018

On the whole it seems safest to choose the rounded-off value 31.02 for the atomic weight of phosphorus.

This investigation has been described in the Communications of the Eighth International Congress of Applied Chemistry, vol. II, pp. 21–36.

The analysis of ferric oxide by reduction in hydrogen, begun last year by Mr. C. R. Hoover (see Year Book No. 10) with terrestrial material, has been completed by the investigation of meteoric material. The following table gives the results of all the experiments:

No.	Terrestrial.		No.	Meteoric.	
	Ratio $Fe_2 : Fe_2O_3$.	Atomic weight of iron.		Ratio $Fe_2 : Fe_2O_3$.	Atomic weight of iron.
1	0.699418	55.845	8	0.699414	55.844
2	0.699428	55.847	9	0.699435	55.849
3	0.699442	55.851	10	0.699417	55.845
4	0.699435	55.849	11	0.699448	55.853
5	0.699421	55.846	12	0.699425	55.847
6	0.699410	55.843			
7	0.699435	55.849	Average	0.699428	55.848
Average	0.699427	55.847	Average of all 12 analyses	0.699427	55.847

It can be seen in the first place that terrestrial and meteoric material seem to be identical. In the second place, the final result is very slightly higher than that found by Baxter, Thorwaldson, and Cobb by the analysis of ferrous bromide (see Year Book No. 9). The results of the two investigations are compared below.

	Ag=107.880.	Ag=107.870.	Ag=107.860.
$FeBr_2$	55.838	55.833	55.828
Fe_2O_3	55.847	55.847	55.847
Average	55.842	55.840	55.837

The rounded-off value 55.84 seems to represent the real atomic weight of iron.

This investigation has been described in the Communications of the Eighth International Congress of Applied Chemistry (vol. II, pp. 37–52).

The investigation upon the atomic weight of arsenic by the titration of arsenic trioxide against iodine, begun some time ago by Mr. G. W. Harris (see Year Book No. 9), has been extended by him to include the use of trioxide which has been sublimed in a vacuum. Contrary to expectation, this material yields, for the atomic weight of arsenic, a slightly higher value than trioxide which has been sublimed in nitrogen. Aside from this lesser reducing power, no difference could be observed between the two sorts of material. At the same time Mr. P. C. Voter, by a very similar method, has compared arsenic trioxide with iodine pentoxide, and has found similar differences in the reducing power of arsenic trioxide sublimed in different ways.

As the matter stands at present the various sorts of material have yielded the following results for the atomic weight of arsenic:

$$Ag = 107.870 \qquad I = 126.920.$$

As_2O_3 sublimed in —	$As_2O_3 : 2I_2$.	$3As_2O_3 : I_2O_5$.
Oxygen	75.037	75.092
Air	74.964	74.969
Nitrogen	74.946	74.940
Vacuum	74.964	74.955

Baxter and Coffin, by the analysis of silver arsenate, obtained the result 74.944 on the same basis (see Year Books Nos. 6 and 7). While it is easy to see how arsenic trioxide sublimed in oxygen, or even in air, might occlude traces of a higher oxide and hence possess less reducing power than material sublimed in an oxygen-free atmosphere, it is more difficult to account for the small but distinct difference between material sublimed in a vacuum and in nitrogen. This difference will be further investigated. It is worth noting, however, that the values for the atomic weight of arsenic obtained by both methods with trioxide sublimed in air, in nitrogen, and in a vacuum agree fairly well with that resulting from the analysis of silver arsenate.

In previous work upon the atomic weight of neodymium (see Year Books Nos. 8 and 9) a series of fractions of neodymium nitrate was prepared by Dr. H. C. Chapin by crystallization from concentrated nitric acid, the most soluble and the least soluble fractions being occasionally rejected. About 2,600 crystallizations were made. These fractions have been converted into chloride and analyzed by Mr. W. H. Whitcomb in exactly the same fashion as in the previous research with pure neodymium material prepared in another way, except that here the chloride, before being weighed, was either fused or heated very nearly to the fusion-point in a current of hydrochloric-acid gas. In this way dry material was secured, while in the previous research, where the chloride was heated only to 350°, a correction for a trace of residual water was necessary. When the chloride was fused it was necessary to avoid a temperature much above the fusion-point, and to avoid prolonged heating, since otherwise what appears to be an insoluble modification of the chloride is formed. By observing the above precautions perfectly soluble material was obtained. The following table gives the result of the analyses; the numbers of the fractions increase with increasing solubility.

Fraction.	Atomic weight of neodymium.	Fraction.	Atomic weight of neodymium.
1+2+3	144.293	10+11	144.272
4+5	144.278	12+13	144.262
6+7	144.283	14+15	144.262
8+9	144.271		

Fractions 1 + 2 + 3, the least soluble, contain a trace of samarium, which is undoubtedly the cause of the slightly higher value obtained from this material, while fractions 12 to 15, the most soluble, contain a trace of praseodymium, which would lower the observed atomic weight of neodymium. Until these impurities can be estimated, the above figures are subject to slight uncertainty. At any rate, they agree very well with the final corrected value previously obtained by Baxter and Chapin, 144.275.

Pure praseodymium salt also has been prepared from about 20 kilograms of crude praseodymium ammonium nitrate furnished by the Welsbach Light Company through the kindness of Dr. Miner. This material has already been subjected to 3,500 crystallizations and is almost ready for analysis.

Mr. F. L. Grover has commenced further investigation of lead bromide in the hope of obtaining the compound in a state sufficiently definite for atomic-weight investigation.

Mr. C. C. Wallace has investigated the change in volume which takes place when the chlorides, bromides, and iodides of lithium, sodium, potassium, rubidium, and cæsium are dissolved in water at various concentrations and various temperatures. The results indicate interesting relationships with various physico-chemical properties of the elements and compounds involved. Incidentally a considerable quantity of cæsium salts has been extracted from mineral sources and will be used for the redetermination of the atomic weight of cæsium as well as in the examination of the physico-chemical properties of its salts.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 753, allotted December 15, 1911. *Investigation of the absorption spectra of solutions,* $1,200. Grant No. 718, allotted March 23, 1911. *Researches on the conductivity, dissociation, and the temperature coefficients of conductivity and dissociation of the more common electrolytes,* $1,000. (For previous reports see Year Books Nos. 2–10.) $2,200

The work of the past year, with Dr. J. S. Guy, on the absorption spectra of solutions has had to do with the following problems:

(1) The effect of high temperature on the absorption spectra of aqueous solutions.

(2) The question as to whether ions and molecules in solution show the same or different absorption spectra.

(3) The measurement of the intensities of absorption lines and bands by means of the radiomicrometer.

The problem of the effect of high temperatures on the absorption spectra of non-aqueous solutions was studied last year, in a steel tube closed at both ends with glass or quartz windows. The steel apparatus was covered electrolytically with gold. While this form of apparatus was very satisfactory with non-aqueous solutions, it did not work satisfactorily with aqueous solutions, since the water-vapor, under the high pressure, found its way

between the steel and gold and caused the latter to separate. This was overcome by using a vessel of brass. This vessel was gold-plated, and it was found that the gold remained tightly adhering to the brass during the entire work. With this apparatus the absorption spectra of aqueous solutions of a fairly large number of salts were studied up to nearly 200°.

It was found that the effect of temperature was in general to widen the absorption bands. The solutions were then cooled gradually from about 200° to ordinary temperatures, and the absorption bands were found gradually to grow narrower as the temperature fell. This was, then, a perfectly reversible process. This widening of the absorption bands with rise in temperature is in complete accord with the solvate theory of solution. Indeed, this result was predicted from the theory before a single spectrum was photographed. Raising the temperature has the same effect as increasing the concentration, *i. e.,* widens the bands. As we increase the concentration we reduce the complexity of the hydrates existing in the solution, and as we raise the temperature we produce the same effect, *i. e.,* the reduction of the complexity of the hydrates; and both processes widen the absorption bands.

The question as to whether ions and molecules have the same or different power to absorb light—have the same or different resonance—is an old one. Indeed, it was thought at one time that the ions are the chief absorbers of light in solution. We now think that the absorption of light by solutions is an electronic phenomenon, and this opens up anew the question of ionic as compared with atomic and molecular absorption.

Our earlier work showed that if ions absorb differently from atoms or molecules the differences were very slight—so slight that it would require special means to detect it. We therefore took a very concentrated solution of the substance in question and passed light through a layer 0.5 cm. deep. This solution was then diluted 100 times, and light was passed through a layer of the diluted solution 50 cm. deep. The second solution was then diluted 5 times and light passed through a layer of the third solution 250 cm. deep, photographing the spectrum in the grating spectroscope in every case. In this way we were increasing the ions present and decreasing the molecules, and could see whether there was any change in the absorption spectrum. In every case the absorption bands were found to be wider in the more concentrated solution, and it is thus highly probable that the ions have slightly different absorption from the atoms or the molecules. In these experiments we were, of course, also changing the complexity of the hydrates present; but a quantitative study of the plates showed that this would not account for the phenomenon.

The third problem was, in reality, the most important one studied during the year—the measurement of the intensities of the absorption lines and bands by means of the radiomicrometer. This was constructed of the alloys of antimony and bismuth and of bismuth and tin, and a very satisfactory instrument was built. By means of this instrument we could not only measure

the intensities of the various parts of a band within the wave-lengths that could be photographed, but could extend the work far down into the infra-red. The most sensitive photographic plate is limited by the wave-lengths λ 2000 to λ 8000. By means of the radiomicrometer we could easily work as far down as λ 20,000 and have planned for extending the measurements to much greater wave-lengths. We have already detected and measured the intensities of a number of new bands in the region of greater wave-lengths, and our work in this field is, comparatively speaking, only begun.

By means of the radiomicrometer we can work *quantitatively* in the field of absorption spectra, and have extended the range of such work about 2½ times. We have studied a number of salts of neodymium and praseodymium. The following interesting and important relation has been found: For the more dilute solutions the *center of the absorption bands moves towards the longer wave-lengths, and the intensity of the bands becomes greater.* A suggestion to account for these facts appeared in a paper recently published.

The work next year with the radiomicrometer will deal with a much larger number of aqueous solutions of inorganic and organic compounds; with a large number of substances inorganic and organic in non-aqueous solvents; with the effect on the intensities of the bands, of temperature, dehydrating agents, etc.

The study of the conductivity and dissociation of electrolytes at different temperatures has made good progress during the past year in the hands of Dr. Wightman, Dr. Kreider, Dr. Howard, Dr. Springer, Mr. Smith, and Mr. Shaeffer. The results of this work, which has been in progress in this laboratory for about a dozen years, has been published as monograph No. 170 of the Carnegie Institution of Washington.

During the past year the work on the organic acids has extended over the whole range of temperature from 0° to 65°, but most of the work has been done between 35° and 65°. Many of the more common organic acids have been studied with respect to their electrical conductivity, over the temperature range above indicated, and over a range in dilution from the most concentrated solution that could be prepared up to from $\frac{1}{1000}$ to $\frac{1}{4000}$ normal. The dissociations have been calculated whenever possible, and the constant for the acid worked out wherever it existed.

The temperature coefficients of conductivity were calculated both in conductivity units and in per cent. Knowing the constants of these substances we know exactly what they will do as acids, under all conditions, and this is the most important reason for carrying out this investigation, especially as it is the first systematic investigation in this field over any considerable range in temperature.

The work with the salts has this year been practically limited to those cases which are more or less exceptional and which have given more or less trouble in the earlier work. These include those salts which are decomposed at more elevated temperatures, especially those hydrolyzed by water.

We have studied the hydrolysis and the dehydrolysis time factors, and some interesting facts have been established. The dissociations of these substances, and the temperature coefficients of conductivity both in conductivity units and in per cent have been worked out. The results of these investigations with the inorganic salts are also incorporated in the monograph just referred to. (Publication No. 170.)

This work will be extended next year to a much larger number of salts and organic acids.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 764, allotted December 15, 1911. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–10.) $4,000

It had previously been shown that, between 0° and 25°, all solutions of cane sugar, including that in which a gram-molecular weight of the substance is dissolved in 1,000 grams of water, obey quite exactly the law of Gay-Lussac for gases. More concentrated solutions have not been investigated. On the other hand, there was no evidence in the conduct of the solutions between these temperatures bearing on the relation of osmotic pressure to the law of Boyle for gases. The osmotic pressures of the ten concentrations of solution which were investigated were all in excess of the calculated gas-pressures of the solute in amounts varying from 6 to 11.5 per cent of the latter; and in general the osmotic pressures were not proportional to the supposed concentration of the solutions. This lack of proportionality of osmotic pressure to concentration was not to be accepted as proof that the law of Boyle does not apply to cane-sugar solutions between 0° and 25°, because it can be explained by supposing the existence of hydrates between these temperatures, the formation of which would have the effect of concentrating the solutions. It was therefore important to investigate the same solutions at temperatures above 25°; since it was probable that, at higher temperatures, any complex relations, due to the appropriation of portions of the solvent by the solute, would become more simple.

The work of measuring the osmotic pressure of cane-sugar solutions at comparatively high temperatures has been in progress during the past year. It was found that the ratios of osmotic to calculated gas-pressure, which are constant, but *apparently excessive,* for each concentration between 0° and 25°, begin in all cases to decline at some temperature between 25° and 30°. In this connection, two questions were to be answered:

(1) At what temperature does the osmotic pressure of each of the ten concentrations of solution become equal to the calculated gas-pressure of the solute?

(2) When, at some temperature, the osmotic and the calculated gas-pressures of the solute have become equal, is the same relation maintained at all higher temperatures?

The first question has been definitely answered. The temperatures at which the unit ratio of osmotic to gas pressure is reached are as follows: For the 0.1 weight-normal solution, 30°; for the 0.2, 50°; for the 0.3 and 0.4, 60°; for the 0.5, 0.6, and 0.7, 70°; for the 0.8, 0.9, and 1.0 solutions, 80°.

The answer to the second question is still incomplete, since we have not yet measured osmotic pressure at temperatures above 80°. All the evidence thus far obtained is, however, of an affirmative character—to the effect, namely, that the unit ratio once reached is maintained at the higher temperatures. The following is an epitome of the results obtained to date:

Temperature.	Weight normal concentration.									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Mean osmotic pressure in atmospheres.									
°										
0	(2.462)	4.722	7.085	9.442	11.895	14.381	16.886	19.476	22.118	24.825
5	2.452	4.818	7.198	9.608	12.100	14.605	17.206	19.822	22.478	25.283
10	2.498	4.893	7.334	9.790	12.297	14.855	17.503	20.161	22.884	25.693
15	2.541	4.985	7.476	9.949	12.549	15.144	17.815	20.535	23.305	26.189
20	2.590	5.064	7.605	10.137	12.748	15.388	18.128	20.905	23.717	26.638
25	2.634	5.148	7.729	10.296	12.943	15.624	18.434	21.252	24.126	27.053
30	2.474	5.044	7.647	10.295	12.978	15.713	18.499	21.375	24.226	27.223
40	2.560	5.163	7.844	10.599	13.355	16.146	18.932	21.803	24.735	27.701
50	2.635	5.278	7.974	10.724	13.504	16.319	19.202	22.116	25.123	28.213
60	2.717	5.437	8.140	10.866	13.666	16.535	19.404	22.327	25.266	28.367
70	....	....	....	......	13.991	16.820	19.568	22.567	25.562	28.624
80	....	....	....	......	......	......	......	23.062	25.919	28.818
90	....	....	....	......	......	......	......	......	......	......
100	....	....	....	......	......	......	......	.... .	......	......
	Ratio of osmotic to gas pressure.									
°										
0	(1.106)	1.061	1.061	1.060	1.069	1.077	1.083	1.093	1.104	1.115
5	1.082	1.063	1.058	1.059	1.067	1.074	1.084	1.093	1.102	1.115
10	1.082	1.060	1.059	1.060	1.066	1.073	1.083	1.092	1.102	1.113
15	1.082	1.061	1.061	1.059	1.068	1.073	1.083	1.093	1.102	1.115
20	1.084	1.062	1.060	1.060	1.067	1.073	1.084	1.093	1.103	1.115
25	1.084	1.059	1.060	1.059	1.065	1.071	1.083	1.093	1.102	1.113
	(1.083)	(1.061)	(1.060)	(1.060)	(1.067)	(1.074)	(1.083)	(1.093)	(1.103)	(1.114)
30	1.000	1.020	1.031	1.040	1.050	1.060	1.069	1.081	1.089	1.101
40	1.003	1.011	1.024	1.038	1.046	1.054	1.059	1.067	1.076	1.085
50	1.000	1.002	1.009	1.017	1.025	1.032	1.041	1.049	1.059	1.071
60	1.000	1.001	0.999	1.000	1.006	1.015	1.020	1.027	1.033	1.044
70	....	....	....	....	1.000	1.002	0.999	1.008	1.015	1.023
80	....	....	....	....	......	......	......	1.001	1.000	1.000
90	....	....	....	....	......	......	......	......	......	......
100	....	....	....	....	......	......	......	......	......	......

The first section of the above table contains the osmotic pressures which were found, while in the second section these pressures are expressed in the form of ratios of osmotic to calculated gas-pressure. The heavy, straight, horizontal lines in the table separate the groups in which the ratio of osmotic to gas pressure is constant and above unity for each concentration from those in which the ratio is either unity or is diminishing, with rising temperature, in the direction of unity. The broken line serves to indicate the temperatures at which the osmotic and calculated gas-pressures of the various solutions become equal. The blank spaces in the tables indicate the field within which the investigation is still unfinished.

The measurement of osmotic pressure at high temperatures is beset with many serious difficulties. The most important of these are due: (*a*) to the great difference between the temperature of the air and the temperature at which the solutions must be maintained; (*b*) to the difference in the expansion coefficients of the diverse materials which are employed in the construction of the cell; (*c*) to the deleterious effect of long-continued heating upon rubber; and (*d*) to the fact that, under the same conditions of temperature, all apparatus made of glass becomes exceedingly brittle and liable to destruction.

During the past year the writer has had associated with him, in the work carried on under the auspices of the Carnegie Institution of Washington, Doctors W. W. Holland and J. C. W. Frazer. Dr. Holland has been engaged upon the investigation continuously for several years, and its successful prosecution is due in a large measure to the skill and experience which he has acquired. Dr. Frazer was associated with the work for several years during its earlier stages, and contributed much to the success with which the greatest obstacles to the measurement of osmotic pressure were finally overcome. He has resumed the work after an absence of four years. Since his return, the investigation of the osmotic pressure of the electrolytes has been given more attention than was possible in the past, and much has been learned that is interesting, and probably important. However, some serious difficulties remain to be overcome before the osmotic pressure of electrolytes can be ascertained with the same ease and certainty as that of the non-electrolytes. So far as the observations made to date can be interpreted, it appears probable that the principal obstacle in the way of measuring the osmotic pressure of electrolytes is due to the effect of that class of bodies on the *colloidal* character of the membrane.

In less important capacities, and as volunteers, Messrs. F. S. Dengler, L. Van Doren, H. O. Eyssell, and J. B. Zinn have aided in the work of the past year. Mr. Van Doren has investigated the relative merits of certain semi-permeable membranes. Messrs. Dengler and Eyssell have studied the problems of the detection and determination of minute quantities of certain poly-acid alcohols whose osmotic pressure it is intended to investigate in the near future. Mr. Zinn has aided in the measurement of the pressures which appear in the tables given in this report.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 763, allotted December 15, 1911. *Researches upon the properties of solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–10.) $3,000

The work of the past year may be outlined as follows:

A series of seven articles has been published describing the researches carried out during the last few years on the effect of salts on the solubility of other salts. The more important results of the investigations were summarized in last year's report.

With the cooperation of Dr. K. G. Falk, two more papers summarizing and discussing existing data on the properties of aqueous salt solutions in relation to the ionic theory have been prepared and published. One of these papers deals with the electrical conductance of dissolved salts and the other compares and discusses the ionization values derived on the one hand from conductance and on the other hand from freezing-point lowering.

The experimental work, which had previously been confined to aqueous solutions, has been extended to solutions in non-aqueous solvents. Dr. F. G. Keyes and Mr. W. J. Winninghoff have made conductance measurements with solutions of iodides in amyl alcohol. By means of a special apparatus which enabled the measurements to be made out of contact with the air, accurate results were obtained even at very high dilutions (*e. g.,* up to 100,000 liters per mol of solute).

From a comprehensive study of the conductivity values obtained in this laboratory with aqueous and non-aqueous salt solutions and of those obtained by other investigators, Dr. C. A. Kraus and Dr. W. C. Bray have been able to show that there is an underlying uniformity in the behavior of all solvents with respect to the ionization of salts dissolved in them. They have found, namely, that a function of the form $(c\gamma)^2/c\ (1-\gamma)=K+D\ (c\gamma)^m$ (in which c is the concentration, and γ the ionization of the salt, and K, D, and m are constants varying with the nature of the salt and the solvent) is generally applicable to univalent salts in any solvent through a very wide range of concentration. They have also shown that in accordance with this function, the mass-action law holds true in all solvents at sufficiently high dilutions. A full discussion of the significance of these results will appear in an article soon to be published.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grant No. 766, allotted December 15, 1911. *The determination of atomic weights and other fundamental properties of matter.* (For previous reports see Year Books Nos. 2–10.) $3,000

The work carried on during the winter of 1911–12 is briefly described under the nine headings given below.

(1) *Further investigation of the atomic weight of silver through the synthesis of lithium perchlorate:*

With the help of a previous grant Dr. H. H. Willard and the author had found that the atomic weight of silver could be very satisfactorily studied through the ratio of lithium chloride to silver on the one hand and of lithium chloride to lithium perchlorate on the other hand. As usual in such investigations, the value of the result depended entirely upon the purity of the three substances concerned. Of these three, the first two (by the methods already elaborated at Harvard) can be made in a state unusually free from contamination. Only the last of the three, namely, lithium perchlorate, remained somewhat in doubt because it was uncertain whether or not every

trace of water could be expelled from this salt at 300°—the highest temperature to which it could be subjected without decomposition. The uncertainty, small in itself, is nevertheless one of great importance in this connection. Preliminary experiments made with the help of T. S. Woodward, and already referred to in the last report, seemed to indicate the purity of the salt, but these were not definitive. Accordingly, with the help of Marshall W. Cox, the author instituted new and more critical experiments. It was found that between 300° and 400°, at which temperature the lithium perchlorate suffers slight loss of oxygen, no water was given off by the salt; and also that when the substance was still further heated until almost wholly decomposed, no water could be found in the gas evolved. This discovery indicates that the salt as formed in the earlier investigation had been as pure as it could possibly be made, and affords substantial support for the atomic weight of silver, 107.871 (o = 16.000), obtained in that investigation. The matter will be prosecuted further in the future.

(2) *Atomic weight of uranium:*

With the assistance of Dr. R. Adams the investigation of the atomic weight of uranium was begun. This atomic weight, the largest of all, has acquired peculiar interest in the last few years because of the suspicion that the element may spontaneously decompose into helium and radium. If this is the case, its atomic weight should be the sum of that of radium and some multiple of that of helium. Hence, an exhaustive revision of the earlier work of the author in conjunction with Dr. B. S. Merigold seemed desirable, because that work was only preliminary in its nature. The problem is a difficult one and no final results are as yet to be recorded, but progress has been made in discovering the errors and side-reactions which must be taken into account.

(3) *Atomic weight of aluminum:*

The investigation mentioned in the preceding paragraph led to the devising of apparatus which could be employed profitably in other researches of a similar kind. One of the most pressing cases to which the apparatus is applicable is that of aluminum, the atomic weight of which has not been seriously studied for over 30 years. Hence, with the help of C. C. Wallace, the investigation of the atomic weight of aluminum was begun. Good progress has been made, not only in preparing pure aluminum salts, but also in effecting preliminary trials of the details of experimentation. This investigation, like the preceding, will be continued in the immediate future.

(4) *Atomic weight of carbon, as found from molecular weights of carbonates:*

Often in the past the carbonates of the more electropositive metals have been used as starting-points for the determination of atomic weights, but usually the results have been of doubtful value because of uncertainty as to the stability and purity of the substances in question. New knowledge of

physical chemistry throws much light on these questions; therefore, with the help of C. R. Hoover, the author has begun a careful revision of the whole subject. Promising preliminary results have already been obtained, and before the issue of the Year Book of 1913 definitive figures are to be expected.

(5) *The heats of neutralization of acids and alkalies:*

With the help of Dr. A. W. Rowe, this subject was continued, adding new acids and alkalies to the list and obtaining further data as to change of the heats of reaction with the temperature and with the dilution of the reagents.

(6) *The heats of dilution of aqueous solutions of acids, bases, and salts:*

In connection with the investigation mentioned under the preceding head, the heats of dilution of the substances concerned were determined with unusual exactness by means of the adiabatic calorimeter. The voluminous data thus obtained, together with those concerning heats of neutralization, form a highly interesting basis for the study of the nature of aqueous solutions of electrolytes and will be subjected to critical study and submitted for publication during the coming winter. This research has extended far beyond the original intention, and bids fair to yield results even more interesting than had at first been expected.

(7) *The heats of combustion of hydrocarbons:*

With the assistance of Dr. Frederick Barry, a number of hydrocarbons of unusual purity have been studied, especially endeavoring to compare substances in homologous series. This work is a continuation of that already published by the author in conjunction with Dr. R. H. Jesse, jr., and affords further basis for the conclusions emphasized in the earlier research.

(8) *The compressibilities of allied organic substances:*

This investigation, which has been in progress for nearly ten years, has as its object the discovery of the relations of the compressibilities of analogous substances to one another and to other properties. Last winter much time was spent in the construction of an absolute pressure gauge, because the other details of the process had been previously carried to a degree of precision exceeding that of the gauges heretofore employed. Mr. J. W. Shipley, who assisted in this work, then proceeded to the determination of the compressibilities of a number of hydrocarbons, alcohols, and other allied compounds, concerning which no satisfactory data are to be found in physico-chemical literature; and the work will be continued next autumn. At the same time, much of the previous unpublished Harvard work on this subject was carefully recalculated, using the appropriate corrections as found with the new gauge, and prepared for publication. The data thus collated were found to confirm indubitably the following rule: The more compressible the substance, the greater is the decrease of its compressibility with increasing pressure. This rule was shown to be consistent with the theory of com-

pressible atoms. Other relations of these significant figures with other properties have been already partly worked out and will soon be published.

(9) *The electromotive forces between amalgams of varying concentrations:* This study, which has already yielded two comprehensive papers (publications of the Carnegie Institution of Washington, Nos. 56 and 118), was carried further with the help of Farrington Daniels. Last winter the electrochemical behavior of very concentrated thallium amalgams was studied—a problem peculiarly interesting because of the great solubility of thallium in mercury. Results have been obtained which even exceed in consistency the earlier work; they indicate very great deviations from the simple concentration law, and may form the basis for important conclusions concerning the nature of solutions in general, as well as to further knowledge of the mechanism of the chemical development of electrical energy.

A long paper on the relations of the compressibilities of organic substances was published in the August number of the Journal of the American Chemical Society; and in the same issue a discussion of recent work on atomic weights, especially that subsidized by the Carnegie Institution of Washington, is to be found. The new work on the absence of water in lithium perchlorate will be presented at the International Congress of Applied Chemistry, and some of the other investigations also may be presented there if they can be codified in time.

The Wolcott Gibbs Chemical Laboratory at Harvard University, designed entirely for research under the author's direction, is almost completed, and will afford much better conditions for exact work than have heretofore been available. Because of this improved opportunity, it is hoped that the generous grants of the Carnegie Institution of Washington may be more efficiently used in the future than in the past.

Sherman, H. C., Columbia University, New York, N. Y. Grant No. 767, allotted Dec. 15, 1911. *Chemical investigations of amylases.* $1,200

The general plan of this investigation is to study thoroughly, with reference to both chemical nature and enzymic activity, at least one representative from each of the three groups of amylases produced respectively by higher animals, higher plants, and fungi. It is believed that such a study will be of much scientific and economic importance because of the wide distribution and important functions of the amylases, and that it will contribute materially to our understanding of the phenomena of enzyme action in general.

At present all enzymes are known by their actions, and the chief criterion of purity or concentration is the quantitative measurement of the enzymic activity. Investigations carried on in this laboratory during 1907–10 resulted in the development of a method for the more accurate measurement of the activity of amylase than was previously possible (Sherman, Kendall and Clark, Journal American Chemical Society, Sept. 1910). Using this

method as a means of determining progress, experiments upon the isolation of the enzyme were undertaken in 1910, and in 1911 preparations of pancreatic amylase having about eight times the activity of any amylase previously described were obtained. As this appeared to be a definite product, its chemical nature and amylolytic power were studied, as fully as the available amount of purified material would permit, and the results were published (Sherman and Schlesinger, Journal American Chemical Society, July 1911 and August 1912). This amylase was able to digest at least 1,000,000 times its weight of starch and to form over 500,000 times its weight of sugar.

With the aid of the grant a similar study of the purification and properties of the amylase of malt was begun in January 1912 and is being actively carried on. Miss M. D. Schlesinger, to whose cooperation the success of the study of pancreatic amylase was so largely due, is devoting her time to this work. The method which had given best results in the purification of pancreatic amylase was found not to be applicable to the amylase of malt, but other methods of the same general nature have been developed and have already yielded several independent preparations having at least two to three times the activity of the strongest malt amylase previously described—a preliminary result which is gratifying in view of the short time in which it has been obtained.

In connection with these experiments upon purification, preliminary data have been obtained upon the chemical nature and activity of this enzyme, the relation between its amyloclastic and its saccharogenic powers, the influence of certain salts upon its activity, and its comparative stability in different solvents and under different precipitants used in its purification. Utilizing the knowledge of properties thus obtained, further experiments are being made with a view to determining in detail the exact method of purification which shall yield a uniform product of the highest possible activity. Only by the study of such a preparation can the long-disputed question of the chemical nature of this important enzyme be settled. Such preliminary observations as have been practicable in connection with the preparations already made point strongly toward a substance of essentially protein nature, as was indicated by Osborne in 1895. Further observations upon the chemical nature and properties of the malt amylase are being made as rapidly as the purified material can be prepared, and it is hoped that a general description of the purified amylase of malt (corresponding to the description of the pancreatic amylase already published) may be ready for publication, and a similar purification of a fungus amylase begun by the middle of 1913. It is planned to emphasize the comparative feature throughout the investigation. Differences in behavior already observed between the three typical amylases selected for study furnish important evidence for the view that these are different substances. This evidence, however, can be made conclusive only by a systematic comparative study of these amylases in the highest possible state of purity.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 769, allotted December 15, 1911. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–10.) $4,000

At the end of the period upon which report was made in the last Year Book study was being made of certain special questions tributary to an inquiry into the agencies that maintain the secular equilibrium of the atmosphere. The work on these was continued until satisfactory results were reached in the more essential cases; in some cases inherent limitations were disclosed that rendered further pursuit inadvisable.

While the general line of research of which this is a part has had for its leading purpose additional light on the fundamental problems of geology, it has also had as an ulterior purpose the application of its results to specific problems. The more fundamental phases of the inquiry are thought to have reached a stage at which an attempt at application to concrete problems may prudently be made. The special problems of geologic climatology perhaps have first claim, as the initial cosmogonic inquiry sprang from them. In pursuance of this thought, the work of the latter portion of the year has been given to assembling and organizing the climatological data of the geologic record for the purpose of defining as sharply as may be the precise nature of the climatic problems involved. This has been done as a step toward the treatment of these problems in accordance with the fundamental conclusions reached in previous inquiries. Good progress has been made in this work.

HISTORY.

Bandelier, Adolf F., New York, N. Y. Grant No. 734, allotted October 19, 1911. *Completion of a documentary history of the Rio Grande Pueblo Indians of New Mexico.* $2,000

A documentary history of the Rio Grande Pueblo Indians of New Mexico is inseparable from that of the Spanish colonists and must include everything connected with the history of New Mexico in general. Since New Mexico first became known to Europeans nearly every century constitutes an approximately distinct period. Documents concerning the eighteenth and nineteenth centuries are quite numerous at Mexico, but not so with what relates to the sixteenth and seventeenth. As the first two volumes of my proposed work will embrace the time up to 1680 only, I directed attention especially to the times between 1536 and the former date, without neglecting any important or interesting source up to the year 1800.

Material from the sixteenth century is scarce in Mexico. I have searched in vain, at Guadalajara and elsewhere, for the official chronicle of Coronado's expedition by Gaspar Pérez de Sotomayor, which existed at the close of the

sixteenth century. It may yet come to light, as well as the papers of Pedro de Tovar, which in the middle of the eighteenth century were held in Culiacan, but which (if they still exist) are unobtainable now, owing to the disturbed state of the country. It may well be that the official chronicle has been transferred to Spain. Of other data of the sixteenth century, or concerning events that transpired during that period, I have secured those contained in the work of Father Tello. I have also copied what the Archbishop of Mantua and General of the Franciscan order, Francisco Gonzaga, published on the missionaries who went with Coronado. That work is based on writings sent to him from Mexico about 1563, but his most important source was the manuscript of Pedro Oroz.

I have also secured two contributions very essential from my standpoint of writing history. To determine distances according to present Spanish standards, when these distances were given four centuries ago, is without value, and distances are often the only means for identification of settlements. I have made copies of the data contained in the work of Vanegas from 1540, which gives the linear measures at that time, with every possible detail, beginning with the smallest unit. Furthermore, I have a full copy of the proclamation in 1577 by Viceroy Gaston de Peralta, establishing the measures to be recognized in New Spain. That proclamation exists only in manuscript and has been loaned to me for purposes of copying it.

Among manuscripts concerning the sixteenth century, though composed in the seventeenth, I must mention the fragment of an unfinished "History of Sinaloa," evidently written by a Jesuit. The passages therefrom which I have transcribed throw an entirely new light on the last years of the life of the negro Estevanico, who was the first to visit the Zuni villages and was there killed.

While in 1887 I made a collection of copies of the documents then accessible, antedating 1680, I have always considered that material to be utterly insufficient for basing upon it a history during the seventeenth century. Since 1887 a few more papers have come to light. After 1680 the documents, owing to military events, became much more numerous. Of the latter I had obtained most at Santa Fé, and they are included in the collection now at the Peabody Museum of Cambridge. My search for material from the seventeenth century, at the National Archives, would therefore have been comparatively fruitless, had I not been informed of another and much more valuable source, which I am now trying to exhaust. This source is the branch of the Inquisition, opened to me by Señor Francisco Fernandez del Castillo, in whose special care the Inquisition papers are at the Archives. The collection comprises more than a thousand folios, and Señor del Castillo is going through it gradually and calling our attention to everything relative to or remotely connected with New Mexico.

Through the Archbishop of Mexico, I may yet obtain a clue to the whereabouts of part of the old Franciscan archives, so valuable for the early periods of New Mexican history, and I shall attempt to investigate the ar-

chives of the former convent of San Fernando, where it may be that some of the documents were saved.

Osgood, Herbert L., Columbia University, New York, N. Y. Grants No. 735, allotted October 19, 1911, and No. 808, allotted March 21, 1912. *Completion of an institutional history of the American Colonies during the period of the French wars.* $1,000

After the first grant from the Carnegie Institution of Washington was made for the prosecution of work on the history of the American colonies during the period of the French wars, Mr. S. A. Wood was continuously employed on material relating to Pennsylvania. He has been through the voluminous papers of James Logan, parts of the Shippen and Peters papers, nearly all of the Penn papers, and then examined some of the Pennsylvania newspapers of the period. On two occasions I have been able to assist him several days at a time. The notes on unprinted Pennsylvania material are now nearly all taken. The same is true of the material relating to Massachusetts, and these are the two largest collections of unprinted records in the possession of any of the original thirteen States. In August Mr. Wood's connection with the work ceased; he has been an efficient helper. His place has been taken by Dr. Newton D. Mereness, an experienced investigator. He will at once put into my hands all the notes which he took for his book on Maryland as a proprietary province, which will save much work at Baltimore and Annapolis. During the next two or three months I plan that Dr. Mereness shall help in New York in the organizing of material already collected and the composition of certain chapters from this.

I have been for several months devoting all my time to the writing of the chapters which will constitute the first volume of the completed work. In rough form these are now more than half done. Work on them and on the arrangement of material for the later volumes will be continued during the present year.

CLASSICS OF INTERNATIONAL LAW.

Scott, James Brown, General Editor, Washington, District of Columbia. Grant No. 712, allotted December 13, 1910. *Preparation and publication of the Classics of International Law.* (For previous reports see Year Books Nos. 9 and 10.) $10,000

Professor Westlake, lately Whewell Professor of International Law at the University of Cambridge and Honorary President of the Institute of International Law, has edited the treatise of Ayala, entitled De jure et officiis bellicis et disciplina militari, originally issued in the year 1582, and to the volume containing the photographic reproduction of the original text he has added an interesting and valuable introduction. John Pawley Bate, reader of Roman and International Law in the Inns of Court, London, has made a

masterly translation of the treatise, which forms a separate volume. The two volumes are expected to appear not later than December 1912.

Several other works are well under way. Rachel's dissertations, published in 1676, and entitled De jure naturæ et gentium, and Textor's Synopsis juris gentium, published in 1680, for each of which works Professor von Bar, of the University of Göttingen, has written an introduction, are being translated by Mr. Bate.

The text of the celebrated treatise of Vattel, published in 1758, in two volumes, and entitled Le droit des gens, has been photographed, and the translation is nearly complete. The introduction will be supplied by Professor de Lapradelle, of the University of Paris.

Immediately after finishing his work on Zouche, Professor Holland accepted the task of preparing an edition of Legnano's tractate (written in 1360, first printed in 1477), entitled De bello, de represaliis et de duello. A beautiful manuscript of the work will be reproduced photographically, as well as the text of 1477, but the translation will be made of the original work without the passages not found in the original, but which were introduced into the edition of 1477. Professor Holland will also see through the press a revised Latin text which will accompany the manuscript and the first print.

It was hoped that the text of Grotius's masterpiece, entitled De jure Belli ac Pacis libri III, first published in 1625, would be issued with an introduction and a translation before the meeting of the Trustees in December 1912. The photographic reproduction of the original text could be issued, but it seems best that the Latin text and the English translation appear at the same time, although they constitute separate volumes. The translation is being made by Prof. John D. Maguire, of the Catholic University of America, and is nearly complete. There are three works of Grotius to be produced. The first, entitled De jure prædæ, although written in 1604, was first published in 1868 from the original manuscript then recently discovered. This manuscript is in the library of the University of Leyden, and the librarian has allowed it to be photographed for reproduction in the series. This very important work, which was a professional opinion rendered by Grotius on a case presented to him when at the bar, is the basis of the masterpiece of 1625, which contains as its Chapter XII the Mare liberum, which was issued in separate form in 1609. The tractate De jure prædæ will be translated by Doctor Maguire as soon as he completes his translation of the De jure Belli ac Pacis. In view of the importance which Grotius occupies, either as founder or as first systematic expounder of the science of international law, and in view also of the relation which exists between the first work of 1604 and the larger and more authoritative work of 1625, it appears best to withhold the introduction and publish it as a separate volume after the three works in question have been issued. Another reason why it is deemed inadvisable to prefix an introduction to the larger work of Grotius is that the volume, as reproduced, is already so large that an adequate introduction would make it unwieldy.

LITERATURE.

Bergen, Henry, Brooklyn, New York. Grant No. 793, allotted January 19, 1912. *Completion of the preparation for publication of the text of Lydgate's Fall of Princes.* $1,800

Dr. Bergen has been engaged in collecting bibliographical data concerning the manuscripts and printed editions of Lydgate's Fall of Princes, and such facts of biography and literary history in regard to Giovanni Boccaccio and his Latin prose De casibus virorum illustrium, and Laurent de Premierfait and his two French versions of Boccaccio's work, as are necessary to an understanding of Lydgate's position as English translator and editor of Laurent's second version; also in examining and collating the manuscripts of Lydgate's Fall of Princes, in order to discover which is best adapted as a basis for the present edition, and in describing the four printed editions of the Fall of Princes and a book issued early in the sixteenth century by Wynkyn de Worde, called the Proverbs of John Lydgate, containing extracts from the Fall of Princes.

Of the work thus outlined, he has practically finished the collection of bibliographical data in regard to the manuscripts and printed editions of the Fall of Princes, and has made progress in the study of the Latin De casibus and its author, as well as of Laurent de Premierfait and his second French version. Although a special study of Lydgate's sources would extend far beyond the scope of the present undertaking, it is nevertheless a matter of considerable interest to point out some of the more important differences in the attitude of these three mediæval authors and scholars to the world about them and its problems.

The Fall of Princes, written between the years 1432 and 1440 by John Lydgate, is an adaptation in English decasyllabic verse, arranged in seven and eight line stanzas, of a French paraphrase, done in 1409 by Laurent de Premierfait, of Giovanni Boccaccio's prose Latin De casibus virorum illustrium. The latter was one of the most popular works of the fifteenth and sixteenth centuries. Translated three times into French, as well as into English, German, Italian, and Spanish, it circulated in hundreds of manuscript copies, some of which are among the most magnificent that have come down to us from the fifteenth century, and passed through nineteen different printed editions, the last of which was issued in 1579. The avowed intention of the author was to exert a moral, humanizing influence on the rulers, civil and ecclesiastical, of his own and future times, by holding up to them, as a mirror of their own very probable fate, the terrifying examples of the many distinguished men and women of history ("beginning at Adam and ending with King John, taken prisoner in France by Prince Edward"), who came to a violent and often miserable end because of their tyranny, vices, cruelty, or uncontrolled ambition. It is obvious that, as a patriotic citizen of the Flor-

entine Republic, Boccaccio had but small sympathy with the majority of the crowned heroes and heroines of his book; and that as the author of this learned didactic treatise, with its fierce invective and biting sarcasm, he was a very different man from the earlier Boccaccio of the graceful introductions to the tales of the Decameron.

The Fall of Princes is thus of considerable literary, historical, and bibliographical interest; nevertheless the chief value of the work to present-day scholars lies in its being the most important document of fifteenth century English of which there is still no modern critical edition. It was last printed in 1558.

Sommer, H. Oskar, Astolat, Camberley, Surrey, England. Grant No. 817, allotted June 12, 1912. *Completion for publication of researches on Arthurian Romances.* (For previous reports see Year Books Nos. 5–10.) $2,000

The following work remains to be done:

(1) Remainder of final revise of volume VI.

(2) Remainder of second revise of vol. VII, about two-thirds of volume.

(3) Final revise of the whole of volume VII.

(4) Remainder of first revise of volume VII.

(5) The Index raisonné to the seven volumes.

MATHEMATICS.

Dickson, L. E., University of Chicago, Chicago, Illinois. Grant No. 809, allotted March 21, 1912. *Completion of a Historical Report on the Theory of Numbers.* $500

In the order named, Professor Dickson worked in the libraries of Cambridge University, Trinity College, Cambridge Philosophical Society, British Museum, Royal Society of London, Bibliothèque Nationale, Université de Paris, St. Geneviève, Institut de France, Göttingen Universität, and Königliche Bibliothek of Berlin.

Lehmer, D. N., University of California, Berkeley, California. Grant No. 807, allotted March 21, 1912. *Assistance in reading proof of his "Tables giving a Complete List of Prime Numbers between the limits* 1 *and* 10,006.721." $300

The proof-reading on the List of Primes proceeds very satisfactorily. Eighty pages have already been read twice and the "inattention constant" of the author and of his assistant seems sufficiently small to make two more readings amply sufficient. As the reading goes now, there will be less than 1 chance in 200 that there will be a single error remaining undetected after four readings.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. Grant No. 755, allotted December 15, 1911. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9, 10.) $1,200

The general trend of our researches for the year was determined by questions arising from the rational planar quintic curve.

(1) The study of this curve suggested a theorem with regard to any planar quintic, namely, that the contact conics touch, by threes, certain lines (Johns Hopkins Circular, Feb. 1912). Professor Coble was led thereby to investigate the general question of the grouping of contact curves by the method of finite geometry. The results were indicated in the above circular and are embodied in a memoir submitted (June 1912) to the Transactions.

(2) The general properties of an involution form were discussed by Coble (Am. Jour., vols. XXXI and XXXII). A construction for the so-called fundamental involution was obtained in a memoir which will appear in the Proceedings of the Cambridge International Congress, which will include also a solution of an important problem of enumeration. The difficulty of this enumeration by methods hitherto available seems to show the desirability of overhauling the general subject of the order of restricted systems of equations.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. Grant No. 770, allotted December 15, 1911. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books 4, 5, 8–10.) $2,000

During the past year the following papers have been published:

(1) On certain expansions of elliptic, hyperelliptic, and related periodic functions. American Journal of Mathematics, vol. 34, pp. 177–202.

In addition to its more general features, this paper contains new and very convenient expansions of the Legendre Elliptic Functions.

(2) The problem of the spherical pendulum from the standpoint of periodic solutions. Rendiconti del Circolo Matematico di Palermo, vol. 32, pp. 338-364.

Among the interesting features of this paper is a new treatment of Hill's linear differential equations with periodic coefficients, and the use of the integral relations for the determinations of the coefficients of the solutions.

(3) A class of periodic orbits of superior planets. Transactions of the American Mathematical Society, vol. 13, pp. 96–108.

This paper proves the existence of, and gives practical means of constructing, periodic orbits of an infinitesimal body revolving around two finite bodies which move in circular orbits. The orbits in question are those which are closed after one synodic revolution. There are three classes of orbits in which the motion is direct, with respect to fixed axes, and three in which it is retrograde; but when the orbits are very large, only one class for motion in each direction is real.

Certain reviews and popular or semipopular articles have been published.

The following investigations have been completed during the last year, and are now in type, though they have not yet been published:

(1) Closed orbits of ejection and related periodic orbits. Painlevé's Theorem. Proceedings London Mathematical Society, Series II, vol. 11, pp. 367–397.

In this paper it is shown that there exist two infinite systems of orbits of ejection of an infinitesimal body having the property that they are also orbits of collision. The direction of ejection is either toward or from the second finite body, and the direction of collision is opposite to that of ejection. The closed orbits of ejection are not periodic, but they are important in the subject of periodic orbits because, as is shown in the paper, each of them is the limit of two families of periodic orbits. In Painlevé's Stockholm lectures on the theory of differential equations it was stated, as a conjecture, that the coordinates and components of velocity of the infinitesimal body must satisfy one analytic condition in order that its orbit should be one passing through a finite body. It is proved in this paper that when one of the finite bodies is small, a point and a speed may be chosen arbitrarily, and that then a direction of motion can be determined as an analytic function of these arbitraries so that the infinitesimal body will pass the chosen point with the chosen speed, so that its orbit will be either one of ejection or one of collision.

(2) Oscillating satellites in the problem of three bodies. The Mathematische Annalen, 39 pages.

This paper contains a general investigation of oscillating satellites, in both two and three dimensions, about the collinear equilibrium points when one of the masses is infinitesimal. When the finite bodies move in circular orbits, six families of periodic oscillating satellite orbits are shown to exist, their properties are established, and practical means are given for constructing them. When the finite bodies move in elliptical orbits, the periodic orbits are closed only after many revolutions, and for a given period (not fully arbitrary) there are twelve geometrically distinct orbits. The discussion involves the treatment of an infinite series of simultaneous linear differential equations having periodic coefficients, and right members which are sums of exponentials multiplied by periodic functions.

(3) Relations among families of periodic orbits in the restricted problem of three bodies. Proceedings International Congress of Mathematics.

This paper gives a synthesis of the retrograde periodic orbits in the problem of three bodies. It shows the connections between the oscillating satellites and the closed orbits of ejection, of these and Poincaré's solutions of the *deuxième sorte,* and of these with his solutions of the *première sorte,* and of all with his solutions of the *deuxième genre.*

A general synthesis of periodic orbits is almost finished, and will appear as a chapter in Publication 161 of the Carnegie Institution of Washington, now in press. It will include the paper presented at the International Congress of Mathematics, and the corresponding discussion of the direct orbits.

The latter have difficulties arising from essential singularities of the functions, and from the necessity of considering infinite periods and asymptotic orbits. Four other investigations are far advanced and will probably be finished during the coming year.

METEOROLOGY.

Bjerknes, V., University of Christiania, Christiania, Norway. Grant No. 756, allotted December 15, 1911. *Preparation of a scientific work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–10.) $1,800

Of the work "Dynamic Meteorology and Hydrography," volume II, "Kinematics," worked out in collaboration with Th. Hesselberg and O. Devik, has appeared. Preparatory work for volume III, "Dynamics," has been continued, with attention directed mainly to the investigation of the influence of friction on atmospheric motions.

At the meeting held at Vienna this year by the "Commission Internationale pour l'Aerostation Scientifique" two propositions presented by Professor Bjerknes were accepted: (1) that in the publications of the Commission gravity potential (measured in "dynamic meters") should be introduced instead of height (measured in meters) as one of the fundamental variables for describing meteorological phenomena; (2) that in the same publications pressure should be used as independent variable instead of height in tabulating the result of meteorological ascents. The introduction of these two reforms in the publications of the Commission will facilitate much the practical application of the methods worked out in the "Dynamic Meteorology and Hydrography."

A third proposition, that in the same publications pressure should be expressed in units belonging to the c.g.s. system (in "millibars" instead of in millimeters or inches of mercury) was also accepted by the Commission, but with the reservation that the reform should not be carried through before having been accepted also by the Permanent Meteorological Committee.

During the year Mr. O. Devik left his position as scientific assistant, and has been succeeded by Mr. H. U. Sverdrup.

NUTRITION.

Osborne, T. B., and **L. B. Mendel.** Grant No. 790, allotted January 18, 1912. *Continuation and extension of work on vegetable proteids.* (For previous reports see Year Books Nos. 3–10.) $15,000

In the report for the previous year experiments conducted in cooperation with Prof. Lafayette B. Mendel were described and the statement made that by methods then employed experimental feeding may be continued long enough to obtain answers to many questions concerning the chemistry of

nutrition. The experiments there described have been continued and extended and the following facts we now consider to be established.

Rats can be maintained throughout their natural adult lives on a diet containing a single protein, if the inorganic constituents and a part of the carbohydrate is supplied in the form of "protein-free milk."

Proteins of diverse chemical constitution, like casein, from cow's milk; edestin, from hempseed; or gliadin, from wheat flour, serve equally well for maintenance.

Proteins which yield no tryptophane, like zein from maize, or gelatin from animal tissues, do not maintain rats in spite of an abundant food intake. Replacing a part of the zein or gelatin with an efficient protein results in maintenance.

Rats can not only be maintained throughout their adult lives on so-called incomplete proteins, like gliadin, which yields no glycocoll or lysine, but even (after long feeding therewith) can reproduce vigorous young and suckle them normally.

The foregoing facts appear to be the most conclusive evidence yet obtained, not only of a synthesis of new protein by the animal, but of some of the amino-acids from which the new protein is constructed.

Growth depends on chemical conditions of nutrition which are different from those of maintenance. A diet which fully meets all the requirements for maintenance may be incapable of promoting growth.

Growth is arrested if the diet contains an insufficient quantity of inorganic constituents or a sufficient quantity in an improper state of combination.

No growth results unless the diet contains a suitable carbohydrate.

Growth fails unless the diet contains a sufficient quantity of protein of proper chemical make-up.

Normal growth is made on a diet free from fat, as well as all other substances soluble in ether.

Normal growth, to nearly full adult size, is made on diets containing, as their sole protein, either edestin or glutelin from the hempseed, glycinin from the soy-bean, glutenin from wheat, globulin from cotton-seed, lactalbumin or casein from cow's milk, glutelin from maize, excelsin from the Brazil-nut, globulin from the squash-seed, or ovalbumin or ovovitellin from the hen's egg.

Very little growth was made on diets whose sole protein was legumelin from the soy-bean.

No growth was made on diets whose sole protein was gliadin from wheat or from rye, hordein from barley, conglutin from the lupine seed, legumin from the pea, or vignin from the cowpea.

Young rats are neither maintained nor grow if the sole protein of the diet is phaseolin from the kidney bean, zein from maize, or gelatin from animal tissues.

These results show that normal growth, to nearly full adult size, can be made with proteins of very diverse chemical constitution, all of which, how-

ever, with the exception of casein, yield all of the amino-acids known to be decomposition products of the so-called complete proteins. None of the proteins which do not yield all these amino-acids, except glycocoll, promote growth, *e. g.*, gliadin, hordein, zein, or gelatin.

Not all of the so-called complete proteins promote growth, *e. g.*, conglutin, legumin, vignin, or phaseolin. Why these leguminous proteins fail has not been discovered.

Young rats which from the time of weaning make a normal rate of growth on the above diets fail to continue to grow after attaining from 75 to 80 per cent of the maximum weight normal for mature animals. After remaining at a constant weight for some weeks these animals decline, and soon die, unless a change is made in the diet. If supplied with a food containing whole milk powder they rapidly regain their lost weight but can not then again grow normally on the original experimental diet. Our experimental foods seem to lack some ingredient present in milk which is essential at some stage of their early growth.

Rats which fail to grow on a diet containing an inefficient protein, like gliadin, live longer than those which grow on a diet containing an efficient protein. The failure of the latter appears to be due to the absence of something in the food essential for the development of some organ which develops during growth.

An artificial mixture of inorganic ions, lactose, and citric acid, in imitation of the "natural protein-free milk" has, in some cases, proved as effective in promoting growth as the natural product. The majority of the experiments have, however, thus far led to a less rapid growth, and for a shorter time.

Experiments with the "artificial protein-free milk" have shown that growth to nearly full adult size can be obtained with a diet which contains only pure protein, starch, lactose, inorganic ions, and citric acid. This diet was entirely free from fat and all substances soluble in ether, and was chemically the simplest food on which an animal has yet been made to grow in any degree corresponding to the normal.

Experiments with the "artificial protein-free milk" have also shown that the chemical constitution of the carbohydrate of the food has a great influence on growth. No growth has been made on any diet in which lactose was replaced by sucrose or any other sugar.

Rats can be kept at perfectly constant weight for many months by feeding with a diet containing "artificial protein-free milk" and gliadin, and an ideal method is thus provided for studying the effect of arrested development.

The addition of a small amount of an adequate protein to a diet containing a protein on which no growth can be made, leads at once to a normal rate of growth.

The combination of gliadin and gelatin, on neither of which alone can growth be made, leads to a very considerable growth.

A certain minimal quantity of protein is necessary for growth. Above this amount growth is proportional to the amount of protein until an opti-

mum is reached. Above this amount growth is not increased by increasing the protein. Too much protein, *e. g.*, 31 per cent, leads to digestive disturbances and death.

The minimal quantity of edestin necessary for normal growth is less than of casein—an unexpected result in view of the chemical make-up of these two proteins.

The capacity to resume growth at a normal rate is long retained and has been observed in one rat over 300 days old, an age at which very little increase in weight occurs in normal animals.

Depleted or stunted animals gain weight faster than the normal rate of growth until they attain a size normal for their age. Thereafter they grow at a normal rate.

Attention has further been directed to a study of methods for estimating the amount of each of the different types of protein contained in seeds. This information is essential to the application of the results obtained by feeding with the isolated individual proteins to feeding with entire seeds. The results of this work are not yet ready for publication.

The anaphylaxis experiments conducted in cooperation with Prof. H. G. Wells have been continued and results of interest obtained which we hope to publish soon.

Much time and money have been expended under the present grant in selecting and installing suitable apparatus for producing adequate quantities of pure proteins and "protein-free milk." This became necessary when it was decided to conduct the feeding experiments on an increased scale.

This work required special studies of the methods to be employed for making large quantities of pure proteins, and attention to the development of these methods, after the new apparatus was put in use.

A breeding department has also been established from which a supply of vigorous rats of known age and parentage can now be obtained. Data are also being collected as to the length of life and normal rate of growth on a large number of animals, so that we shall soon have much more accurate data than was before available. Such data are necessary for a proper judgment respecting the outcome of the feeding experiments with artificial diets.

The results of the year's work have appeared in the several papers, which are listed in the bibliography, pp. 44, 45.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. Grant No. 772, allotted December 15, 1911. *Completion of work on the Permian Vertebrate Fauna of North America.* (For previous reports see Year Books Nos. 2, 4, 8–10.) $2,000

Since January 1, 1912, a study of the literature of the Red Beds of Oklahoma, Kansas, Texas, New Mexico, and Colorado has been made; the months of July, August, and September were spent in the field in those States, study-

ing the beds in which vertebrate fossils occur, with the view of attempting an interpretation of the conditions under which the vertebrate animals of the Permian or Permo-Carboniferous period lived and developed. Considerable time has also been spent, in collaboration with Dr. S. W. Williston, of the University of Chicago, in preparing the manuscript of a book on the "Permian Vertebrates of New Mexico." This manuscript will be completed in the fall of 1912 and submitted to the Carnegie Institution of Washington for publication. This work will form an additional volume to the series of monographs, publications Nos. 55, 146, and 147, on the Permian vertebrate life of North America.

The field work now on hand is in preparation for the publication of a volume dealing with the conditions of vertebrate life in the Permian or Permo-Carboniferous period, the character of the deposits, the paleogeography of North America at the time, etc.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. Grant No. 773, allotted December 15, 1911. *Investigation of the vertebrate paleontology of the Pleistocene epoch.* $3,000

Since the beginning of the year Professor Hay's time has been devoted principally to studying the Pleistocene mammalian materials in the U. S. National Museum. About five weeks of July and August were spent in the museums of Philadelphia, New Haven, and New York, examining and taking notes and photographs of the materials seen there. A paper was recently published in the Smithsonian Miscellaneous Collections in which the author attempted to distinguish the faunas which succeeded one another during the Pleistocene (vol. 59, pp. 1–16, 10 figures).

Wieland, G. R., Yale University, New Haven, Connecticut. Grant No. 774, allotted December 15, 1911. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4, 6–9.) $3,000

The first half of the current year has been largely devoted to extending the series of thin sections of fossil cycads. Among the trunks sectioned is one that may perhaps rank as the most striking plant of any kind in full fruit ever recovered—a trunk bearing between 500 and 600 ovulate cones, mostly complete and with well-conserved dicotyledonous embryos. This remarkable example of a monocarpic trunk was discovered by Dr. Darton, of the U. S. Geological Survey, and later turned over to me by the officials of the U. S. National Museum for study and record.

The results of exploration in Oaxaca noted in a previous report are now in course of publication by the Instituto Geologico de Mexico in the form of an extended memoir on the Liassic flora of the Mixteca Alta.

The general plan of work outlined in preceding reports and the things proposed or suggested as desirable to be done remain unchanged. The study of the silicified cycads has aided much in establishing a new basis from

which to take a census of early Jurassic plants, and this it is now assured will shed much new light on the course of evolution in pre-Angiosperm times. The task before us, therefore, is the accurate field measurement of the more promising mid-Mesozoic plant-yielding strata of the globe and investigation of personally collected series.

PHILOLOGY.

Loew, E. A., Oxford, England. Grant No. 757, allotted December 15, 1911. *Continuation and completion of researches and publication of the "Scriptura Beneventana."* (For previous reports under auspices of the Roman School see Year Books Nos. 9 and 10.) $1,500

The work of the past year has been a continuation of that of previous years. Five months were spent in Italy, the remainder of the time in Oxford. The book on the "Beneventan (or South Italian) Script" is now ready for press. It seemed advisable to include in the book itself the catalogue of Beneventan MSS., which I had intended to put in a second volume. To do this it was necessary to revisit the libraries of the Benedictine monasteries of Monte Cassino and La Cava, besides those of Naples (Nazionale, Brancacciana, and Archivio di Stato), Salerno, and Rome (Vaticana, Vallicelliana, Chigiana, Vittorio Emanuele, Corsiniana, Casanatense, and Angelica).

Previous investigations in preparation for this book had been made in the libraries of Florence, Lucca, Milan, Monza, Novara, Vercelli, and Ivrea; of Berne, St. Gall, Einsiedeln, and Zurich; of Munich, Bamberg, and Carlsruhe; of Vienna, of Paris, of London, and of Oxford. I am at present engaged upon the description of the 100 plates of facsimiles of Beneventan MSS., and both the book and the plates are expected to be issued early next year.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 775, allotted December 15, 1911. *Study of the diffusion of gases through liquids.* (For previous reports see Year Books Nos. 4, 5, 7–10.) $500

Since the author noticed in 1895 that the Cartesian diver used in his lectures grew heavier from year to year, it occurred to him that definite measurements of the rate of loss of buoyancy would be fruitful. They would bear directly on the coefficient of diffusion of the imprisoned gas through the liquid in which the diver is floating. It would be easily possible to vary the liquids and gases, within and without, under conditions of an accurately determinable diffusion gradient. Ultimately the transfer of single molecules of a gas through the intermolecular pores of the liquid is in question, so that the experiment might throw definite light on the molecular relations involved.

The experiments of the report now in preparation in Chapter I were made during a period of eleven years with an ordinary glass Cartesian diver with

a small aperture. As they led to satisfactory values of the diffusion coefficient (*i. e.*, grams of gas transpiring per second across an orthogonal square centimeter, in case of a unit pressure gradient) of the imprisoned air through water, and to a plausible value of the mean viscosity of the imaginary medium within the molecular pores of the liquid through which a single molecule of the gas virtually transpires, the investigation was taken up on a more extended scale, for different pairs of gases.

In Chapter II of the report the author has modified the diver in form and the endeavor is made to obtain equal areas in the section of the cylindrical swimmer and the annular space without, in order to conform more closely to the equation of diffusion. The theory of the phenomenon and the errors involved are carefully discussed. It appears that even for mixed gases the volumes diffusing (not the masses) are always fully determinable. The accuracy essentially depends on the measurement of absolute temperature and of barometric pressure, and should therefore be of an order below 1/2730 per 0.1° C. or 1/7600 per 0.1 mm. of mercury. As the masses of gas contained are usually much less than 10^{-2} gram, even in case of air, the weight less than 0.000004 gram is determinable, showing the remarkable sensitiveness of the method. Moreover, in the region of constant temperature the limit of sensitiveness is immensely greater.

To elucidate the phenomenon, experiments were begun with the transpiration of imprisoned hydrogen into air, in which the resultant diffusion is always unidirectional, outward from the diver. Initially rates as large as 5 mg. per day were obtained, which eventually decreased to values 100 times smaller. Improvements of this experiment showed lower initial rates, decreasing to a constant value equivalent to a fixed diffusion coefficient.

The diffusion of air into air through water proceeded with a definite mean rate throughout the two or three months of observation, of about 32×10^{-6} grams per day, corresponding to the diffusion coefficient of 1.00×10^{-13}. in c.g.s. units. But the daily march of the loss by diffusion was systematically irregular, a result finally referred to the change of solubility of the gases in water, with temperature. The consequence of this is absorption and release of gas, as temperature falls or rises, respectively, during the occurrence of the otherwise steady diffusion. In the long series the temperature effect was eliminated by the method of least squares.

Much more striking were the phenomena encountered in endeavoring to find the coefficient of diffusion of hydrogen through water into hydrogen, in which ultimately the loss of weight of the diver was about 8.8×10^{-6} grams per day, corresponding to the diffusion coefficient 1.75×10^{-14}. Referred to molecular conditions the molecule can be regarded as moving through a medium about 15 times as viscous as ordinary hydrogen, whereas in case of air the medium would be about 13 times as viscous as air. The daily march of results in the hydrogen observations was most striking, inasmuch as the diver first lost weight at an initially enormous rate for two days, then rapidly

gained weight at a decreasing rate during the ensuing ten days, and thereafter assumed the steady rate of loss for months. Changes were as a rule abrupt. It was found that a similar doubly inflected progression of results usually occurs unless all manipulations at the outset are conducted, not in air, but in a medium of hydrogen, or in general of the gas within the diver. Otherwise the imprisoned gas is at once contaminated by diffusion of the surrounding gas into it. It is not perhaps fully appreciated by chemists that gases, otherwise pure, if stored over water, are at once contaminated with air, by diffusion. In fact, a gas, *A*, in the swimmer, in presence of gases, *C*, *D*, etc., can not escape by diffusion, until the sum of the partial pressures of *B*, *C*, etc., is equal to or greater than the pressure equivalent of the head of water under which the gas *A* is submerged. Before that the gas of the environment will diffuse into the diver against the hydrostatic pressure of the head of water, *i. e.*, apparently up hill. The same explanation accounts for the enormous inflation of the microscopic air-bubbles in the liquid, when the surrounding atmosphere is some other gas, like hydrogen.

Other diffusion experiments, air into hydrogen, oxygen into hydrogen, hydrogen into air, etc., were eventually pursued through months and completed in a similar manner and with similar results. The graphs obtained are throughout striking. It is feasible to derive the differential equation for these phenomena, but as might be expected, from the complications in question, it could not be integrated. Finally it is interesting to note that if the diffusion coefficients are given, the densities of the gases diffusing at a constant rate may be computed; or from another point of view, the degree of purity of the gas so diffusing may be ascertained.

The sensitiveness of weighing in case of the Cartesian diver, where the whole apparatus is quite submerged in water or some other liquid and capillary forces are out of the question, naturally suggested the application of this method for the measurement of high potentials in case of the absolute electrometer. For this purpose the whole condenser, as described in Chapter III of the report, is submerged in a clear non-conducting paraffin oil, while the movable disk of the electrometer is floated on a Cartesian diver. The difference of weight of a charged and uncharged condenser is determinable, the former in view of the electrical pressures being less. It may then be shown that the absolute difference of potential of the plates, other things being equal, varies as their distance apart and as the square root of the difference of the manometer pressures which are just compatible with flotation, in the case of the charged and uncharged condenser, respectively. By keeping the difference in question constant, potentials may be absolutely measured in terms of the distance apart of the plates from about 50 volts to indefinitely large magnitudes.

These experiments suggested a variety of other methods. Thus the disk of the absolute electrometer, now kept in air, was buoyed up and held in place on a hydrometer, with its body submerged in oil, where the capillary

forces are small. Particularly interesting results were obtained when the hydrometer was a very thin, straight, aluminum tube, at right angles to the light aluminum plate of the condenser. It is shown that for a difference of potential of the disks (supposed horizontal), not too large, there is a stable and unstable position of the movable disk, the former below the latter. The disk, therefore, rises from its fiducial position in the uncharged condenser to a definite height. As the difference of potential increases this height increases until at a transitional height both stable and unstable positions coincide. For greater differences of potential the disk passes without interruption from the lower plate (guard ring) to the upper plate of the condenser. If the difference of potential is constant the same phenomena may be evoked on diminishing the distance apart of plates of the condenser, by lowering the upper plate on a micrometer screw. Potentials may then be absolutely measured in terms of the distance apart of the plates, at which the continuous rise of the disk first occurs.

Similar experiments, such as the treatment of Coulomb's law when one of the repelling bodies is a Cartesian diver, the repetition of Mayer's experiments when the charged metallic bodies are floated in oil in a charged guard ring, etc., were devised.

Finally, the experience gained in Chapter III of the report, in relation to methods of filling the diver with a gas in an environment of the same gas, a condition rigorously necessary if the gases are to remain adequately pure for diffusion measurements, suggested the repetition of certain of the experiments in Chapter II. These are given in Chapter IV, where the diffusion of gases through other liquids and solutions is also treated.

Howe, Henry M., Columbia University, New York, N. Y. Grant No. 698, allotted December 13, 1910. *Determination of the refining temperature of steel.* (For previous reports see Year Books Nos. 6–10.) $500

As explained more fully in Year Book No. 10, p. 234, hypo- and hyper-eutectoid steel respectively give birth progressively to pro-eutectoid ferrite and pro-eutectoid cementite as they cool slowly through the transformation range, say 900° to 725° C. These pro-eutectoid components exist in part as a network, *i. e.*, as cell-walls inclosing the allotriomorphic crystals or grains of austenite from which they spring, and in part they remain within those grains. The network structure itself is transient, coming slowly to a maximum distinctness and again breaking up. During the present year the behavior of these pro-eutectoid constituents has been studied further. Though the actual precipitation of both ferrite and cementite is probably very rapid, their coalescence into readily visible masses has been found to be unexpectedly slow, and that of ferrite slower within the transformation range than below it, a fact referable to the greater quantity of ferrite present in the latter case. At 750° the ferrite network of a steel of 0.40 per cent of carbon

reaches its greatest distinctness in between 36 and 108 minutes; at 700° in between 4 and 9 minutes, though after this the coalescence of ferrite continues.

The degradation of the ferrite network seems due primarily to the belated coalescence of additional ferrite into masses which conceal that network, though the balling-up of the network itself through surface tension probably contributes.

The internal ferrite and cementite are slower to coalesce into visible masses in cooling down, and are more quickly reabsorbed by the neighboring austenite when the temperature again rises through the transformation range, than the network, a fact which, at least in the case of cementite, may be related to the pseudomorphism of the internal masses and the probable idiomorphism of the network.

But at constant temperature within the transformation range, after the cementite network has reached its maximum prominence, the internal cementite coalesces into masses which, probably through some optical illusion, are much greater than our theories explain, and even conceal the network. Still later, the internal cementite gradually disappears, by a process akin to sublimation, by progressive resolution in the surrounding austenite and reprecipitation. This migration of the cementite usually again makes the network very prominent by thickening it up, but it sometimes forms large, shapeless cementite masses. A like process may perhaps go on in the case of ferrite also.

Experiments to determine the upper boundary of the transformation range seem nearly complete.

In addition to the foregoing, which refers to the iron-cementite diagram, considerable work on the iron graphite diagram has been done. Some of the flake-graphite of cast iron has been proven to be formed before solidification has progressed far. While this may be primary graphite, it may be formed by the very rapid resolution of solid cementite in the molten iron and its reprecipitation as idiomorphic graphite.

Experiments to determine the lower boundary of the transformation range of this diagram have been begun.

Nichols, E. L., Cornell University, Ithaca, New York. Grant No. 777, allotted December 15, 1911. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–10.) $3,000

I. *Fluorescence and phosphorescence:*

During the year a large amount of time has been given to the preparation of the report recently published by the Carnegie Institution of Washington under the title "Studies in Luminescence," by Edward L. Nichols and Ernest Merritt (publication 152, pp. VIII + 225. 1912).

In the meantime we have extended our observations on the fluorescence and absorption of the uranyl salts with reference to the more detailed deter-

minations of the numerous series of bands contained in their spectra when excited at the temperature of liquid air. Preliminary experiments have also been made looking to the production of a series of phosphorescent compounds having aluminum oxide as their basis, and apparatus for this work has been purchased and installed.

Mr. H. E. Howe has continued his development of photographic methods for the quantitative determination of the distribution of energy in banded spectra with special application to fluorescence and phosphorescence and has begun the measurement of the fluorescence bands and absorption bands of fluorescein, tetrachlor fluorescein, eosin, and tetrachlor eosin. These substances have been recently prepared in great purity by Prof. W. R. Orndorff, to whom we are indebted for the opportunity of studying their spectra. In these measurements Mr. Howe is using a photo-electric cell to determine the intensity of the light transmitted by different portions of the photographic plate, as recently described by Professor Merritt and myself in a paper before the American Physical Society (Physical Review, XXXIV, p. 475).

Mr. G. E. Thompson has been further engaged in the investigation of photo-electric effects in cells having a fluorescent electrolyte, and Mr. T. B. Brown has continued his studies of kathodo-luminescence.

Mr. C. E. Power has begun the assembling of apparatus for the determination of the phosphorescence of certain of the sulphides of Lenard and Klatt at high temperatures, with special reference to the temperatures at which their activity ceases.

Dr. Frances G. Wick, at the physical laboratory of Vassar College, has made spectro-photometric measurements of the fluorescence, absorption, and surface color of the double cyanides of platinum.

II. *The effects of temperature upon physical properties:*

In this work it is proposed to subject substances, under conditions which admit of accurate determinations of some given property, to the widest possible range of temperature and thus to gain more knowledge of the effect of temperature upon various physical constants than has hitherto been available.

The following investigations in this very broad field are now in progress:

Dr. A. A. Somerville is determining the electrical conductivity of metallic oxides through a range of temperatures from that at which the conductivity first becomes appreciable up to 1100° C. Preliminary reports were presented to the American Physical Society on March 2 and April 27, 1912 (Physical Review, XXXIV, pp. 311 and 399), and a further paper will be read at the October meeting of the Society.

Dr. F. A. Molby, assisted by Mr. A. L. Huestis, has measured indices of refraction of optical glasses by the method of interference between —190° C. and 100° C. A preliminary paper, giving some of the results, was read at the meeting of the American Physical Society on March 2, 1912 (Physical

Review, XXXIV, p. 232). It is proposed to extend this work to other glasses and through a greater range of temperature, for which purpose we have secured test pieces made of numerous Jena optical glasses of known composition, and by a variation of the method to determine the indices of liquids. Dr. Molby has likewise applied his method to the measurement of the coefficient of expansion of invar steel between 100° C. and —190° C. (Physical Review, XXXIV, p. 79).

In the somewhat similar problem of the effect of temperature on the transmission of light by colored glasses, Prof. R. C. Gibbs, with the assistance of Mr. K. S. Gibson, has continued his investigations by the means of the spectrophotometer between —190° C. and 400° C. It is proposed to extend these measurements upon the same samples to the infra-red spectrum.

Progress has been made by Prof. J. S. Shearer and Mr. C. C. Murdock in their study of the specific heat of gases at various temperatures; by Mr. C. C. Bidwell in the comparison of optically measured temperatures of glowing bodies with the corresponding "black-body" temperature; and by Mr. A. R. Nottingham in the study of the specific heat of steam.

PHYSIOLOGY.

Loeb, Leo, St. Louis, Missouri. Grant No. 582, allotted January 12, 1909. *Study of the toxic action of the venom of Heloderma suspectum.* (For previous reports see Year Books Nos. 6, 7, 8, and 9.) $500

During the years 1911 and 1912 the studies on the biochemical character of the venom and on the absorption of the venom by various substances were concluded. We also undertook a study of the action of Calmette's cobra-antivenin on the venom of *Heloderma*.

Our work is now completed and ready for publication. It considers various aspects—morphological, physiological, and biochemical—of the problem, and we hope that it may serve as the basis for a still more thoroughgoing analysis of the effects of venom on the animal organism.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 778, allotted December 15, 1911. *Study of differentiation and specificity of homologous vital substances.* (For previous reports see Year Books Nos. 9 and 10.) $1,500

The research on starches in relation to genera and species has been completed and is now in the hands of the printer. It will appear in two volumes as publication 173 of the Carnegie Institution of Washington. This investigation is being followed by studies along related lines of inquiry.

POLITICAL SCIENCE.

Rowe, L. S., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 701, allotted December 13, 1910. *Study of federal system of Mexico.* (For previous reports see Year Books Nos. 8–10.) $1,500

In 1910, under a grant from the Carnegie Institution of Washington, Dr. Rowe began the study of the Mexican federal system. During his stay in Mexico he completed the following chapters:

Chapter I. The basis of the Mexican federal system. Antecedents of the Constitution of 1857.
Chapter II. The provisional organic law of 1856 and the Constitution of February 5, 1857.
Chapter III. Amendments to the Constitution of 1857.
Chapter IV. Organization of the Federal Government; Relative position of the Executive, Legislative, and Judicial authorities.

In 1911 Dr. Rowe returned to Mexico for a period of two months, and in 1912 for a similar period for the purpose of continuing the investigations. These trips were made without any further grants from the Institution; their purpose has been to collect material for the completion of the two most difficult chapters of the work, viz:

Chapter V. The constitutional position of the States.
Chapter VI. Constitutional guarantees in the Mexican political system.

The difficulty encountered in securing accurate data for these two chapters is due in large measure to the wide discrepancy between law and fact in the Mexican constitutional system. The repeated suspension of constitutional guarantees during the recent revolutions has furnished much valuable material for the final chapter of the work.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. Grant No. 758, allotted December 15, 1911. *Continuation of experimental study of heredity in small mammals.* $1,000. Grant No. 739, allotted November 27, 1911. *For the purpose of obtaining in South America living specimens of Cavia to be used in hybridization experiments with the guinea-pig, and for the prosecution of such experiments.* $1,500. (For previous reports see Year Books Nos. 3–10.) $2,500

Dr. John C. Phillips and the grantee have continued on a larger scale than in any previous year their selection experiments with rats. As a result they continue to obtain more and more modified conditions of the color pattern which they have been attempting to alter by "mass selection." They conclude that selection is a genuine creative agency in evolution and animal breeding, not a mere sorting-out agency of unit-character combinations. In this they substantiate Darwin's opinions in so far as those opinions differ from current "mutational" and "pure-line" ideas.

In investigations with mice, guinea-pigs, and rabbits, the grantee has had the continued assistance of C. C. Little, John Detlefsen, and E. C. MacDowell respectively. Papers embodying the results obtained are nearly ready for publication.

Several new lines of experiment have been started with guinea-pigs brought from Peru in January 1912. Assisted by a special grant, the writer went to southern Peru in November 1911, and was there able to secure guinea-pigs of three distinct sorts: (1) a small wild species of *Cavia,* probably *cutleri,* about half as large as the domesticated guinea-pig, of a squirrel-gray color; (2) a supposedly feral guinea-pig resembling the golden agouti domesticated variety; (3) domesticated guinea-pigs as kept for food by the natives of Peru at the present time.

All these sorts breed readily with the domesticated guinea-pig kept in the United States and Europe. Indeed the ancestors of the last undoubtedly came from South America only a few centuries ago. But the wild ancestral species is still unidentified, and the main object of the Peruvian expedition was if possible to discover this ancestor and see what new varieties, if any, could be derived from it by crossing. What success has been attained remains in part to be determined.

Hybrids derived from the wild species crossed with the guinea-pig all resemble the wild species, but give promise of attaining larger size. Their fertility is as yet problematical. Hybrids from the supposed feral stock are not uniform in character, but give clear indications that that stock contained admixtures of domesticated blood; it may even have come wholly from that source. The first cross with both the feral and the native Peruvian stock has produced a variety of guinea-pig hitherto unknown to us. Further results are awaited with interest.

Five papers have been published by the grantee and two by C. C. Little based on results obtained under these grants. (See Bibliography, pp. 41–43).

Gudger, E. W., North Carolina State Normal and Industrial College, Greensboro, North Carolina. Grant No. 528, allotted May 12, 1908. *Investigation of the breeding-habits and life-history of the gaff-topsail catfish.* (For previous reports see Year Books Nos. 7 and 9.) $300

The grantee spent the last ten days of May at Beaufort, North Carolina, in the endeavor to get the early stages (the only ones lacking) in the development of the gaff-topsail catfish, for the drawings of which a grant was made some years ago.

Naples Zoological Station, Naples, Italy. Grant No. 759, allotted December 15, 1911. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2–10.) $1,000

During the last term the two Carnegie Institution of Washington study tables at the Zoological Station were occupied by Professor Lambert, of

Tufts College, Massachusetts (see Year Book, 1911, p. 241); to Dr. Davenport Hooker, of Yale University, New Haven, Connecticut, from April 4 to May 21, 1912, and Dr. David H. Tennent, of Bryn Mawr College, from May 13 to June 20, 1912.

Dr. Hooker continued his experimental researches on the growth of isolated tissues, and histological elements in the serum of Selachian embryos; and Dr. Tennent studied the hybridization in the eggs of echinoderms.

Riddle, Oscar, University of Chicago, Chicago, Illinois. Grant No. 799, allotted February 15, 1912. *Preparation for publication of the manuscripts of the late Dr. C. O. Whitman, provision for care and maintenance of the Whitman pigeon collection, and continuation of investigations necessary for completion of Dr. Whitman's manuscripts.* $4,400

The more important accomplishments of the present year are:

(1) The partial arrangement of the parts of the Whitman manuscripts that bear on the "shifting of dominance."

(2) Other work on these manuscripts, including the examination, typing, and duplication of parts, and the assembling of most parts bearing on the subject of "behavior."

(3) Very extensive investigations on a comparison of the chemistry and energy content of the male- and female-producing eggs of pigeons; it is as yet too early to state the results of these studies.

(4) The discovery of evidence of the existence of two kinds of females—one more masculine than the other—among the hybrids of *Turtur orientalis* and *T. alba.* In other words, some evidence is found that sex is not a true alternative character, but a graded character.

(5) The continuation and extension of some of Professor Whitman's studies on the method of inheritance in pigeons, and on the nature and meaning of mutants. Of considerable interest here is the result that three of the fourteen F_1 offspring of an apparent "mutant," *T. orientalis,* mated with a normal *T. orientalis* showed *traces* of the mutational character; two hatched still later showed this character almost complete; these five were all hatched *late* in season from birds overworked in reproduction—conditions similar to those under which the original mutant was obtained.

(6) Findings on the physiology of reproduction which show: (*a*) that fertility of the bird's egg is affected by feeding of sodium benzoate only when fertility is weak; (*b*) new evidence that a sudden change in the growth rate of ova of the fowl occurs when the ova reach a diameter of 6 to 7 mm.; (*c*) that the chemical composition of the membrane (follicular) surrounding the egg has a very high phosphatid content at the time when rapid growth begins; (*d*) the subgerminal cavity of the sauropsidan blastoderm and egg is due primarily to imbibition of water from the albumen by the egg-yolk, and can arise in unfertilized eggs independently of the development of an embryo.

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